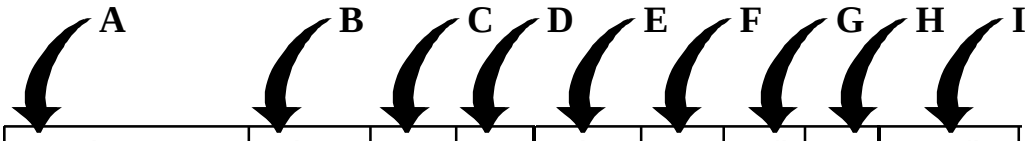
APPENDIX B: ARDB ROAD MAP

Exhibit B-1 is a guide to the Automated Requirements Data Base (ARDB) listed in Appendices C, D, and E. The ARDB is the repository for the requirements analysis and traceability data. Each column has been identified with a letter. The corresponding definition is listed below.



Rqmt Id	Update	Status	RTM	Tech Int	Trace	Quality	Test	Appendix F
DADS0010	10/7/94	2			0	0	0	F-1
DADS0020	10/7/94	2			0	0	0	F-10
DADS0070	10/7/94	2			0	0	0	F-3
DADS0100	10/7/94	2			0	0	0	F-24
DADS0110	10/7/94	2			0	0	0	F-12
DADS0120	10/11/94	1			0	1	0	F-9
DADS0130	10/11/94	1			0	0	0	F-7
DADS0140	10/11/94	1			0	1	0	F-2
DADS0145	10/11/94	1			0	0	0	F-6
DADS0150	10/11/94	1			0	1	0	F-14
DADS0160	10/11/94	1			0	1	0	F-21
DADS0170	10/11/94	1			0	0	0	F-18
DADS0175	10/7/94	2			0	0	0	F-22
DADS0180	10/11/94	1			0	1	0	F-30
DADS0190	10/7/94	2			0	0	0	F-31

EXHIBIT B-1: ARDB Guide

A - The requirement identifier.
B - Set by the IV&V analyst when an analysis or review begins, or when an analysis is completed. Each time the Status is changed, the update field is also changed.
C - Status of the requirement analysis (0=Evaluation reported to NASA, 1=Evaluation complete, 2=IV&V Review in progress, 3=Analysis in progress, 4=Not yet analyzed).
D - TBD link to RTM, which will import requirement text directly from that tool.
E - Technical Integrity requirements analysis for this requirement. This column contains an icon which points to an embedded MS Word 6.0 document.
F - Traceability rating for this requirement (number from 0-4). See appendix A for details.
G - Quality rating for this requirement (number from 0-4). See appendix A for details.
H - Testability rating for this requirement (number from 0-4). See appendix A for details.
I - Refers to the page number in appendix F where details concerning the analysis may be found.

Testability - Requirements must be stated in quantitative terms that can be translated into acceptance criteria.

Key Word(s) - Acceptance Criteria

Rating Definition

3 Major - Not testable.
2 Moderate - Testable, but acceptance criteria cannot be formulated.
1 Minor - Testable; minor clarifications are needed.
0 No testability problems identified.

Evaluation Guidelines

Requirements testability focuses on whether requirements are testable, contain enough information to suggest a test approach, and provide quantitative criteria to evaluate test results.

Assign If

3 Requirement does not provide a testable function or deliverable. Summarize requirement deficiencies.

2 Requirement yields testable function, but does not give acceptance criteria, allow formulation of acceptance criteria, or infer a test approach. Describe, in the engineering rationale, what additional functional detail and/or references are needed in order to define a test approach and/or quantitative acceptance criteria.

1 Most acceptance criteria requirements can be directly extracted from the requirement text. Some clarification is needed for some terms and/or definitions in order to eliminate any minor assumptions. Describe what clarification is needed or assumptions related to this requirement.

Consistency	Requirement is not in agreement with overall mission and/or desired functionality. Describe, in the engineering rationale, why the requirement is not in agreement. Suggest rewording or other changes (i.e. placement in another section), that are needed.	Agreement of the requirement with overall mission goals and/or desired functionality is questionable. Describe, in the engineering rationale what gives rise to questionable wording, and suggest alternative wording or other changes (i.e. placement in another section), that are needed.	Requirement is in agreement with overall mission and/or desired functionality, but clarifications are needed; **and/or** multiple terms are used for the same functionality. Describe, in the engineering rationale, what clarifications are needed, or what terms are used interchangeably.
Flexibility	Requirement states the design outright. Specifies COTS and/or technologies which greatly restrict system design options. Identify, in the engineering rationale, what these constraints are; recommend alternative wording.	Requirement implies use of a specific design method, and/or tooling. Identify, in the engineering rationale what these constraints are, and recommend alternative wording.	Requirement slightly limits design alternatives. Identify, in the engineering rationale what these constraints are and why they are limiting to the design.

EXHIBIT A-3: Quality Problem Severity Guidelines

ATTRIBUTES	MAJOR	MODERATE	MINOR
Accuracy	Requirement contains erroneous values, information, and/or direction that could result in serious failure of system implementation. Identify, in the engineering rationale, where the inaccuracy arises; consequences to the implementation of the requirement as written, and suggest possible correct values/functionality, if known.	Requirement contains values, information, and/or direction that is in error, but implementation will not likely result in serious system failure. Identify, in the engineering rationale, where the inaccuracy arises; consequences to the implementation of the requirement as written, and suggest correct values/functionality, if known.	Requirement contains editorial errors, typos, etc. Recommend, in the engineering rationale, appropriate wording, spelling, etc.
Ambiguity	Requirement cannot be reasonably interpreted. Implementation of this requirement using any interpretation will likely result in the intended functionality not being implemented. Describe, in the engineering rationale, why the requirement cannot be interpreted; the consequences of not changing the requirement, and suggest alternatives for rewording to make the requirement understandable.	Requirement can be interpreted in more than one way. One of those ways may yield wrong or undesired functionality. Describe, in the engineering rationale, each interpretation, and what part of the requirement, as written, causes the ambiguity the possible consequences of not changing the requirement, and suggest alternatives for rewording to make the requirement understandable.	Requirement needs some clarification, but basic functionality is not in question. Describe, in the engineering rationale, what clarifications are needed, and suggest alternative wording to provide this clarification.
Completeness	Requirements for a major function are missing or incomplete. Describe, in the engineering rationale, what the missing functions are and what needs to be added to correct the requirement insufficiency.	Requirements are written at a level of detail which does not fully specify the desired functionality. Explain, in the engineering rationale, the appropriate level of detail required	Requirement states all necessary functions, but some clarification is needed. Explain, in the engineering rationale, the clarification required.

QUALITY ATTRIBUTES	KEY WORDS	DEFINITION	EVALUATION GUIDELINES
Accuracy	Error	Requirements must be free from error.	Accuracy evaluation focuses on correctness of the requirement.
Ambiguity	Interpretation	Requirements must be stated so they are not open to interpretation.	Ambiguity evaluation focuses on the interpretation of each requirement. In this context, the content of each requirement is examined for clarity to ensure that only one interpretation is implied.
Completeness	Detail	Requirements must completely specify the product.	Completeness evaluation focuses on the existence of an overall goal or function being entirely specified, void of insufficient function or detail.
Consistency	Agreement Harmony Accord	Requirements must be consistent with one another, with interfacing subsystems, and with those at the next higher and lower levels.	Consistency evaluation focuses on the existence and the validity of the logical and the functional relationships between the requirements (i.e.,uniformities and standards in notation; technical non-contradictions in concept and approach, architecture and structure)
Flexibility	Design Constraints	Requirements must be stated to allow design alternatives and system adaptability within the allowable bounds of system constraints.	Flexibility evaluation focuses on the degree to which the requirement constrains the design options of the developer or limits his design approach. (Note: This guideline must be applied appropriately to the requirement document level.)

EXHIBIT A-2: Requirement Quality Evaluation Guidelines

Quality - Requirements must be of high technical quality: accurate, unambiguous, complete, flexible, and consistent.

Rating	Definition
4	Unknown (not yet analyzed; t.b.d).
3	Major - serious substantive problems exist.
2	Moderate - some manageable substantive problems exist.
1	Minor - clarity and/or editorial problems exist.
0	No quality problems identified.

Evaluation Guidelines

Quality evaluation guidelines are illustrated in Exhibit B. Problem severity determination guidelines are illustrated in in Exhibit C.

Traceability - Each requirement must be correctly derived from one higher level specification and all peer-to-peer (same level) relationships must be correctly identified.

Key Word - Linkages

Rating	Definition
3	Major - Requirement has no linkage to any next-higher level specification.
2	Moderate - Requirement linkage is questionable or peer linkage(s) are incomplete.
1	Minor - Linkages exist, but could be strengthened by rewording, editing, etc.
0	No traceability problems identified.

Evaluation Guidelines

Requirements traceability evaluation focuses on the existence and validity of the logical connections (linkages) between requirements. In this context, the substance of each requirement is examined only to the extent needed to determine connectivity correctness.

Assign	If
3	There is no link from this requirement to any next-higher level specification, **OR** requirement is incorrectly linked to a next-higher level specification. Recommend, in the engineering rationale, to which next-higher level specification this requirement should be linked, and why.
2	a) Requirement linkage to next-higher level specification is questionable. Recommend, in the engineering rationale, why linkage is questionable, how the linkage might be fixed, or to what other requirement the linkage should be made. b) Necessary linkages to peer requirements are incomplete, or do not exist. Recommend, in the engineering rationale, how the linkage could be made complete, or to which peer requirement(s) the linkage should be made.
1	Correct linkages exist, but wording of requirements could be changed to strengthen the linkage, make it clearer, etc. Recommend, in the engineering rationale, what changes should be made to strengthen the linkage.

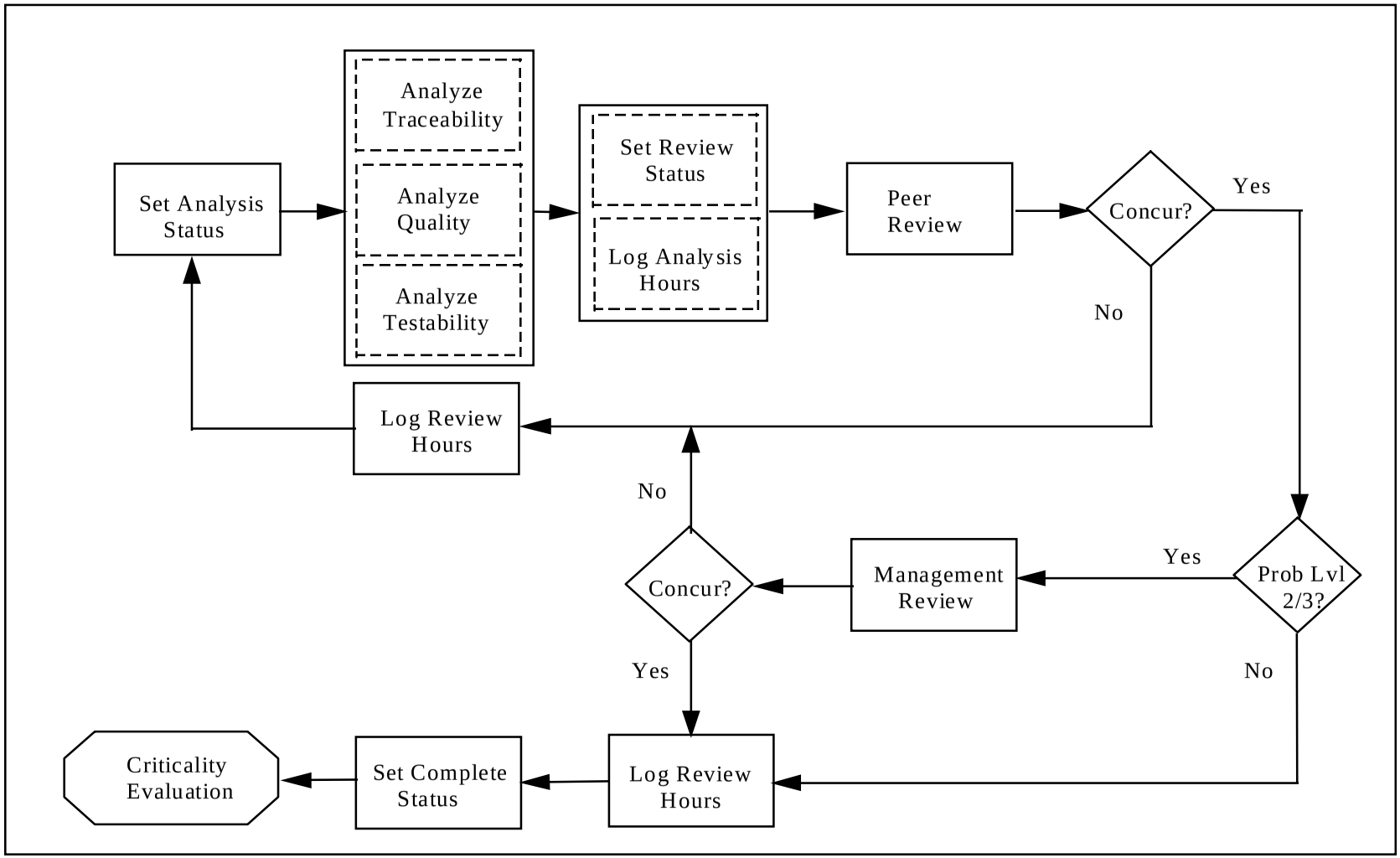


EXHIBIT A-1: Requirements Analysis - Technical Integrity Evaluation Process

Traceability Verification (Existence) Problem Severity Guidelines		
Major	Moderate	Minor
There is no linkage from this requirement to the next higher or lower level specification. Recommend, in the engineering rationale, to which higher or lower level specification this requirement should be linked.	Necessary linkages to peer requirements are incomplete, or do not exist. Recommend, in the engineering rationale, how the linkage could be made complete, or to which peer requirement(s) the linkage should be made.	N/A

Traceability Validation (Analysis) Problem Severity Guidelines		
Major	Moderate	Minor
The requirement is linked incorrectly to the next higher or lower level specification. Recommend, in the engineering rationale, to which higher or lower level specification this requirement should be linked.	a) Requirement linkage to next higher or lower level specification is questionable. State in the engineering rationale why the linkage is questionable, how the linkage might be fixed, or to what other requirement the linkage should be made.	Correct linkages exist, but wording or requirements could be changed to strengthen the linkage, make it clearer, etc. Recommend, in the engineering rationale, what changes should be made to strengthen the linkage.

Assign requirement trace rating using composite Existence and Validity criteria described in the above tables. Assign rating which corresponds to the most severe problem.

The description of each category and associated evaluation criteria are described on the following pages.

There are two categories of traceability analysis: parent-child traceability and peer-to-peer traceability.

Parent-child traceability - Requirements at Level 2 and below should trace to one or more parent requirement to assure that the scope of the system is not being expanded. Conversely, requirements from Level 1 down should trace to child requirements to assure that the scope of the system is not being reduced. Parent-child requirement trace analysis is focused on two criteria, scope and completeness. Peer requirement trace analysis is focused on consistency of requirements

> Scope - The linkages for each requirement are analyzed to verify that the child requirements are within the scope of the parent requirement. Since many requirement at Levels 1, 2 and 3 are compound requirements, the trace linkages are often many to many. In situations where a child requirement has multiple parents, each parent requirement must be examined to determine if the child requirement is within scope.
>
> Completeness - The linkages for each requirement are analyzed to verify that the parent requirement is fully addressed in one or more child requirements. All aspects of the parent requirement must be addressed in the linked child requirement(s). Generally, child requirements are expected to extend the level of detail which is given in the parent requirement.

Peer-to-peer traceability - Peer-to-peer requirement linkages are analyzed to determine if requirements have consistency across system boundaries. Peer linkages typically exist for requirements which define interfaces between system components or services. For example, wherever a requirement states that a data item is received from, or is provided to, an external element, a comparable peer requirement should exist in the external element. As part of the Key Interface Analysis (ISVVP Section 4.9) IV&V examines peer linkages for system components which are subject to Interface Requirement Documents. Peer linkages for intra-component boundaries (e.g., between the ECS PGS and DADS) are analyzed as part of the Requirements Task (ISVVP Section 4.5).

Whenever peer linkages are provided, each linkage is analyzed for correctness and consistency. Correctness means that the linked requirements are truly peers. Consistency means that the peer linked requirements correctly describe the same requirements from the point of view of the two interfacing components.

Whenever peer linkages are not provided, each interface requirement is analyzed to determine if a peer should exist. If a peer requirement is found, it must meet the correctness and consistency criteria described in the previous paragraph.

The results of linkage problems identified during trace analysis and during trace validity are assessed using the following severity guidelines.

APPENDIX A: REQUIREMENTS ANALYSIS GUIDELINES

Each requirement at levels 2, 3, and 4 will be evaluated in terms of three technical integrity categories: 1) traceability, 2) quality, and 3) testability. Categories will be evaluated independently of each other (i.e., it is possible that a requirement will be evaluate badly in one category and well in another). The result of each evaluation will be quantified using a rating scale of 0 (no problems) to 3 (major problems) according the specific definitions associated with each category. A rating of 4 is a "flag" which indicates an unknown state: not yet analyzed or t.b.d. pending further information. The technical integrity evaluation process is illustrated in Exhibit A.

Each evaluation will include a brief engineering rationale which substantiates the assigned rating. Whenever an evaluation indicates multiple problems at differing levels of severity, the assigned rating will reflect the most severe case. The engineering rationale will sufficiently characterize all (most severe and other) identified problems so that corrective measures can be effectively applied to the collection.

Each requirement metrics data base entry will include current IV&V evaluation status information. Status will be expressed by a numeric code indicating what work (if any) is in-progress and the date on which the current status became effective:

Status	Meaning	As of Date
4	Not Yet Analyzed	n/a
3	Analysis in-progress	mm/dd/yy
2	IV&V Review in-progress	mm/dd/yy
1	Evaluation complete	mm/dd/yy
0	Evaluation reported to NASA	mm/dd/yy

The technical integrity requirements evaluation process will include an analysis activity followed by review(es) before the results are formally reported to non-IV&V personnel. Requirements which evaluate, in every category, as 0 or 1 only require peer review. Requirements which evaluate, in any category, as 2 or 3 require peer review followed by IV&V management review.

Requirements traceability evaluation focuses on the existence and validity of the logical connections (linkages) between requirements. Trace analysis (validity) is distinct from trace verification (existence) which is discussed in ISVVP Section 2.1. (Trace verification is focused on verifying that trace linkages exist and that the linkages are between existing requirements.) Trace analysis is a part of requirements analysis and is done to determine if the trace linkages have technical validity. In general, IV&V analyzes linkages identified by system developers. In some cases, where the linkages do not exist, trace analysis may be extended to determining the linkages between two requirement levels. The process for evaluating existing trace linkages is similar to the process of identifying the linkages.

6.2 Recommended Solutions to Important Problems

Data Definition

There does not appear to be a consistent, structured approach to EOSDIS data definition (see discussion in section 5.1.4.1). Data definitions need to be developed and maintained in a hierarchical structure. The use of hierarchies should also be applied to the system components. This creates parallel structures for data items and system components so that an appropriate level of detail is expressed at each level of the hierarchy. When a data item is referenced, it should be possible to find that item within the EOSDIS data definition structure, determine what higher level data item it is a part of, and what lower level data items it contains. Without a systematic approach to data definition, the probability of inconsistent development increases. The situation becomes more critical for external interfaces. The transition from the old element based architecture to the new services based architecture increases the need for good data definition. A method of linking the data definitions between the two architectures needs to be devised. We recommend that the Project develop a consistent, structured set of EOSDIS data definitions and maintain them in an ESDIS CCB controlled database.

Configuration Control of Trace Linkages

The traceability data for linking requirements from level 1 to level 2 and level 2 to level 3 should be placed under formal ESDIS configuration control.

6.3 Risk Management Recommendations

Performance - We recommend a continued aggressive EOSDIS modeling activity and the establishment of measurable performance bounds. Performance bounds are minimum and maximum performance levels that are likely to be encountered.

Evolving Standards -. We recommend that stable portions of evolving standards be identified so that the implementation can incorporate these portions. In addition, we recommend continued close contact with the standards groups. Where the time frame of standards evolution is incompatible with system implementation needs, ESDIS should consider definition of internal standards.

6.0 RECOMMENDATIONS

This section presents a series of recommendations for future requirements analysis work, recommended solutions to important problems and risk management recommendations.

6.1 Areas Requiring Further Analysis

Requirements Analysis Scope - The ECS requirements analysis conducted thus far should be expanded to include the full scope of the EOSDIS IV&V requirements analysis methodology. This includes performing technical integrity analysis of the ESDIS Level 2 requirements, EDOS requirements, and ECS level 4 requirements. Also, the results of the Ecom IV&V contractor's analyses should be incorporated in the overall EOSDIS requirements analysis to provide a comprehensive view of the status of EOSDIS requirements. Requirements analysis should be repeated each time requirements at any level (1, 2 or 3) are rebaselined.

Level 3 to Level 4 Traceability - The ECS Level 3 requirements are structured according to the (old) segment / element architecture (PGS, EOC, etc.). The ECS Level 3 requirements are the contract specifications between the ESDIS Project and HAIS and are, therefore, the basis against which the delivered system must be evaluated. The ECS Level 4 requirements are being organized according to the (new) services architecture presented at the ECS SDR. This shift in architecture can be expected to present some challenges for defining trace linkages between level 3 and level 4. Due to the fact that traceability is essential to certification of delivered ECS releases, we recommend that IV&V focus on developer traceability efforts to make sure that traceability is carried through to Level 4 and into the later life-cycle stages.

Problem Tracking - The current requirements analysis activity has flagged ECS requirements problems in the ARDB. The value of these metrics is to support tracking of progress in resolution of requirement problems. We recommend that IV&V track ECS requirement problem resolution through the life-cycle.

User Satisfaction - In the user satisfaction area, it is important to map the user scenarios to the Level 3 requirements. This mapping would then be used to assess requirements coverage and sufficiency.

ECS Release Requirements Analysis - ECS release-specific requirements will be targeted at specific levels of capability and performance. The requirements analysis activity documented in this report has had a wide focus covering the total scope of the ECS. The focus of future IV&V release analyses will be narrowed to address the specific capabilities and performance levels allocated to a release.

- The analysis indicated that the Level 2 requirement, 1441 regarding generation and distribution of photographic data products is not in the Level 3 requirements. In spite of recent advances in the techniques for digital data visualization and image display, demands for photographic products still exists and inclusion of this requirement is recommended.

- Phased implementation of the ECS has the potential to strongly effect user interaction during transition from one version to the other, as addressed in Level 2 requirements 1458, 1461 and 1462. It is found that these requirements do not have links to ECS level 3 requirements. As these requirements are very important in achieving long term user satisfaction they should be suitably incorporated at level 3.

- The requirement for providing easy access to the EOSDIS is achieved by providing user access through a variety of communication links from dial up lines supporting basic users with low levels of query and browse activity (with limited resources), to those with high speed network links and advanced workstation facilities with access to all ECS services. The variety of communication links /networks in the public domain used for access to the ECS play an important role in user satisfaction. It is essential that users are made fully aware of the extent of service they can expect with the limitations imposed by the communication links and the terminal equipment.

5.3 Trends and Projections

This purpose of this section is to highlight measurable differences observed between the results of the current requirements analysis and previous ones; and to project the implications of those differences into the future (i.e., whether they appear to be diverging from, or converging toward, requirements stability). Since this is the first analysis performed by IV&V (i.e., the first datum), it is not possible, at this time, to document a trends analysis or project trends into the future.

Requirements changes are a fact-of-life that will, almost certainly, occur over the entire life of the EOSDIS. The EOSDIS technical success depends, to a significant extent, on achieving a requirements change rate that stabilizes at some acceptable level, coupled with the ability to accurately evaluate, *a priori*, the effects of proposed changes to identify those that can be implemented without major cost or schedule impacts. Subsequent requirements analyses will define and evaluate the metrics needed to make these predictions with progressively increasing levels of confidence.

requirements, the Level 4 requirements present the next opportunity to remove ambiguities by stating the specific intent.

5.1.4.3 Traceability Problems

A significant set of traceability issues exist have been identified. They represent the most significant concern uncovered during the requirements analysis activity.

Lack of Linkage Configuration Control - The linkage data used during this analysis came from MTPE and HAIS. It is not under ESDIS configuration control. This means that multiple, inconsistent sets of linkage data can exist and be used across the Project. Correct, complete and controlled traceability data is essential for maintenance of requirements baselines, requirements change control, system development and IV&V.

Missing Linkages - Twenty four Level 2 Volume 1 requirements do not have links to level 3 requirements. For seven of these requirements, no obvious level 3 child requirements could be found. This represents possible omissions in the level 3 requirements which could translate into missing functionality in the delivered system.

Excessive Numbers of Linkages and Weak Linkages - These linkages between Level 2 Volume 1 and Level 3 ECS requirements will make it more difficult to make effective use the linkage data. For example, they will be a hindrance to assessing the impact of a proposed requirements change because they make it necessary to examine a large numbers of linked requirements, most of which are not affected by the proposed change. These linkages will also present problems when requirements are linked to tests.

Missing peer-to-peer linkages - Peer-to-peer linkages are useful in defining internal and external ECS interface. Their absence increases the possibility of interfacing components being implemented incorrectly and failing to function together properly at system integration testing.

5.2 User Satisfaction

In EOSDIS, which is an evolutionary system, with anticipated technological advances, and increased expectations of the scientific community, achieving user satisfaction and maintaining it during the life time of the system, needs a concerted effort throughout the life cycle. The evolution of the design of EOSDIS is to be monitored to ensure that the system fully meets the requirements of the user community. Requirements analysis is an important IV&V activity which gives us an opportunity to ensure that the high level requirements are being adequately addressed at lower levels to result in user satisfaction.

The functional and performance requirements have been specifically examined for their technical integrity from the perspective of ensuring user satisfaction. Results of the analysis of the requirements along with the identified potential problem areas are given earlier in Section 4 of this report. Some of the problems potentially effecting user satisfaction are given below:

problems are not systematically corrected, the groups responsible for implementing the individual components may not find and resolve the inconsistencies prior to design and development. In that case, the problems would not be detected until the integration and test stage, leading to rework and delays during I&T.

5.1.4.2 Meta Requirements

Many ECS requirements at Level 2 and Level 3 are not definitive. They are subject to future clarification and definition. This can be seen in requirements related to performance, requirements on the use of standards and requirements which are ambiguous or incomplete. These categories of "meta' requirements are described in more detail below :

Performance - Many (most) performance requirements are tied to data volume and data rates that are TBD. It will be difficult to determine if the system design and implementation are adequate until later in the implementation process when the performance drivers have been established. Until specific performance requirements are known, the focus must be on the growth potential of the design. The concern is that the design be capable of scaling-up to the actual performance requirements.

Evolving Standards - A number of requirements call for adherence to standards which are not yet complete or stable. A good example is the DADS requirements for adherence to the IEEE mass storage reference model.

```
DADS1700    Where appropriate, the DADS shall comply with the
evolving guidelines and standards emerging from the IEEE-CS MSS
Reference Model.
```

The intent of this requirements is reasonable but it may prove difficult to meet.

Ambiguous / incomplete requirements - There are a large number of ECS requirements which use words like 'support' that leave the specific intent of the requirement unclear. PGS-0910 is an example of this type of requirement:

```
PGS-0910    The PGS shall have the capability to support analysis
of algorithm test results.
```

At some point, someone in the development process will have to decide what "support" means in the context of this requirement. The earlier in the development process that these decisions are made, the better. If the ambiguities are left unresolved, they will be inherited by the software component designers or even the unit designers and coders. At that late stage it is unlikely the designers will be able to devote the time and resources necessary to correctly translate the requirement. The designers may also feel compelled to resolve the ambiguity within the scope of their assigned component or unit, since no external service or interface has been identified. This means that the interpretation will be limited and may not satisfy the original, full intent of the requirement. Short of making a large number of changes to the baselined ECS Level 3

functionality built into the EOC/ICC complex at GSFC. The potential exists that the "internal" ICC will not be developed to interface to the EOC in the same way as an external (ASTER) ICC. Since many EOC and ICC requirements are identical, the EOC and ICC functionality may be combined in the same software modules. The implemented EOC code could be tightly coupled to the ICC code so that changes to either EOC of ICC requirements could lead to problems. The danger is that this will lead to two types of ICCs with different and inconsistent functionality. Both the internal ICC and the ASTER ICC should use the same interface to the EOC and the ICC and EOC code should not be commingled.

5.1.3 Communications and System Management Segment Requirements

For both ESN and SMC, linkage deficiencies (weak, incomplete parent/child linkages and missing peer-to-peer linkages) make it difficult to develop a system which meets the original intent without rework in the later life-cycle phases. The inadequacy stems from the fact that most linkages were established ad hoc. If a common methodology is enforced, there exists a better chance to deliver a system with minimum rework.

In addition, major problems exists between the ability to develop the interface between the SMC and the different ECS elements. Inadequate data definitions and undefined support functions in SMC make it difficult to assess the type of data to be passed between the ECS elements and the SMC. This ambiguity may lead to a system being built which meets requirements, but does not meet the original intent. As a result, it may require multiple iterations, at significant resource costs, to deliver a system which satisfies the original intent.

5.1.4 Overall ECS Requirements

This section discusses conclusions on technical integrity of the ECS requirements overall.

5.1.4.1 Data Definition

Data definition and data flow diagrams have inconsistencies internal to the ECS and between the ECS and external components. Internal to the ECS, this problem is found in requirements about data items which are not consistent with the conceptual data flow tables and conceptual context diagrams.

The problem is seen again in looking at ECS-to-external component data flows. Data definition tables and data flow (context) diagrams exist in a number of documents, including the ECS Level 3 Spec, the IRDs and the ECS Operations Concept Document. The data items in these documents are presented at different, and apparently unrelated, granularities. Also, the system components that the data flows between are at different granularities (ECS versus DAAC versus IMS, for example).

Consistent and complete data definition is critical to successful definition of interfaces between internal ECS components and between the ECS and external components. If data definition

5.0 CONCLUSIONS

This section presents conclusions reached based on the results obtained during the requirements analysis activity. The conclusions address both the technical integrity of the requirements and user satisfaction issues.

5.1 Technical Integrity

Conclusions on technical integrity for each of the ECS segments are presented in the following sections.

5.1.1 Science Data Processing Segment Requirements

A total of 522 SDPS requirements were evaluated for technical integrity. Three major problems were found, all related to traceability (see requirements SDPS0085, PGS-0420, and PGS-0430). In all three cases, links to Level 2 requirements were not specified. Although rated as "severe", the analysis for each of these requirements indicates that parent (Level 2) requirements do exist for these requirements, and with minimal effort, appropriate links can be established. Two additional traceability issues were found which do not appear in the technical integrity analyses: 1) the omission of peer links, and 2) excess number of links to Level 2 requirements. The overall technical integrity of the SDPS requirements can be improved once a common methodology for defining linkages (both peer and parent-child) across all ECS elements is established and implemented.

The majority of the remaining SDPS requirements issues were minor and addressed various quality factors. The small number of testability issues were actually secondary, stemming from quality issues such as ambiguous terminology or missing details. Minor issues such as these pose minimal impact to the system, and will most likely be resolved at the next level of design.

5.1.2 Flight Operations Segment Requirements

In general, no major problems exist with the technical integrity of the Flight Operations Segment (FOS) Level 3 requirements and these requirements should provide an adequate baseline for Level 4 and PDR work. The level of detail is consistent with the intent of the document and should provide a roadmap for implementing FOS functions. The allocation of requirements into the FOS service areas facilitates the understanding of the major system capabilities and the definition of IV&V test sequences and functional threads. The technical integrity of the requirements can be augmented by continuing to analyze and define traceability information thus providing a cohesive system specification to develop and test.

A concern for the Flight Operations Segment is the nature of the EOC to ICC interface. Separate collections of requirements exist for the EOC and the ICC but it is not clear that the EOC to ICC interface will be treated formally. All of the EOS instruments, except ASTER, will use the ICC

until system integration test failures occur. This, in turn, complicates and delays the integration phase.

- **Inconsistency Between Peer Requirements -** This problem exists where the list of data items being transferred from one element to another is specified differently in two peer requirements. This can lead to incorrect system implementation. If not corrected the problems will surface at integration tests between the affected elements. This results in adverse cost and schedule impacts.

4.5.4.2 Traceability Problems

- **Missing trace linkages** - Twenty four ESDIS level 2 Volume 1 requirements do not have children in the ECS Level 3 Requirements. Suitable ECS Level 3 child requirements were found for 17 of these requirements. No suitable child requirements were found for 7.

- **Excessive numbers of linkages and weak linkages** - Too many linkages have been established for some Level 2 Volume 1 requirements. The same situation also exists for some ECS Level 3 requirements. In addition, many linkages are weak. Excessive numbers of linkages and weak linkages diminish the overall value of traceability.

- **Missing peer linkages** - For most ECS elements, peer-to-per linkages have not been established. Establishing peer linkages makes it possible to identify and correct requirements inconsistencies between interfacing components. They help to maintain consistency when requirements are changed.

4.5.4.3 Testability Problems

- Many testability problems found resulted from one or more quality problems identified for the requirement. Where a requirement is ambiguous it is naturally difficult to define acceptance criteria.

- Other testability problem resulted from function triggers not being specified. Most functional requirements do not specify what triggers the function. Sometimes you can make an educated guess by looking at the data that is input to the function.

4.5.4.4 Lessons Learned Not Addressed in Requirements

Level 2 and Level 3 requirements do not address specific lessons learned from other GSFC data and information systems. For example, requirements that the system be able to cope with bad data. The system should not crash in the face of unexpected or bad data. The system should also institute a process to resolve the problem. Also, requirements are needed for proper handling of time transitions such as new year, new decade (millennium), leap days, etc. The system should not behave incorrectly when any of these types of transitions occur.

4.5.4.1 Ambiguity Problems

The use of words like "support" in numerous requirements leaves the specific intent of the requirement unclear. In some cases the purpose of a set of requirements can be determined from the text sections preceding the numbered requirements. However, this is not always the case. The combination of ambiguous wording of some requirements together with incomplete descriptions of purpose and context can lead to requirements misunderstandings and incorrect or incomplete implementations.

- **Requirement does not itemize which functions it applies to -** This situation is seen in FOS requirements which say the FOS must support a training mode and a test mode. They do not say which functions have to be included in the training mode or the test mode. The expectation is that all functions within the segment will be included unless the developer can make a convincing argument that some are unneeded, impossible to include or impractical (too costly) to include.

- **Requirement is not complete or self contained -** There are several different cases of this situation.

  1. The missing information in the requirement is directly derivable from the introductory text, requirement context, DFD, etc.

  2. The missing information can be inferred from the introductory text, DFDs, and surrounding requirements

  3. The missing information can be inferred from knowledge of the overall EOSDIS and ECS program and general practice for ground systems at GSFC.

  4. The requirement is truly ambiguous

  We should not consider cases 1 and 2 to be ambiguous. The introductory paragraphs are just as contractually binding as the numbered requirement statements. The main impact is incomplete traceability and the possibility of incorrect interpretation. Case 3 deserves to be flagged (depending on how widely the program/GSFC knowledge is known) and Case 4 definitely should be flagged.

- **Inconsistent Terminology -** A number of inconsistencies in terminology use occur throughout the ECS Level 3 requirements. They result in some potential for misinterpretation and subsequent implementation problems.

- **Data Definition and Data Flow Problems -** Inconsistencies and errors in data definitions and data flows exist in the ECS requirements. A typical example is when a data item in the context diagram is not included in the requirement statement. In the SMC requirements the data definitions are not as detailed as in the other elements. There does not appear to be a structured, consistent approach to EOSDIS data definition. At a minimum, these problems increase the effort required to correctly define internal and external ECS interfaces. They also increase the probability of implementation errors affecting interfaces. Interface errors can be latent and not surface

4.5.3 Communications and System Management Segment Requirements

The identified problems for the ESN and SMC are analyzed in this section. The analysis is geared toward identifying the severity of the problem and the probable impacts thereof in the different life-cycle phases. The order of the analysis is from the most severe to the least severe impacts.

- **Missing peer linkages**. Most links showing the association between the ECS segments and the external interfaces do not exist. The absence of these linkages make it difficult to identify incomplete, inconsistent or missing requirements. Thus, specific component tests may succeed, but the integrated components may fail to provide the intended services. The resources required to fix the problem may be significant, resulting in milestone slippages or cost overruns.

- **Questionable Level 2 linkages**. The number of weak and incomplete linkages to the Level 2 requirements hide the *main* purpose behind deriving a particular level 3 requirement. In testing the system, a large number of loosely coupled linkages serves to hide the essence of what is to be accomplished, making it difficult to differentiate the core and supplemental services. The ability to identify the impacts of a requirement change, in all phases of the program, are affected by the linkage deficiencies.

- **Broad scope.** The lack of detail in defining the support capabilities impact all phases of the life-cycle. It will be difficult for the developer to develop an architecture for undefined capabilities. The developer will most likely build a set of capabilities that fit the schedule, and not necessarily the intended function. If the functions are described more precisely, unnecessary rework can be avoided.

- **Inconsistent terminology or functionality.** The inter-segment messages in ECS for the SMC are sketchy, at best. Because of inconsistencies in the terminology describing data sent from the SMC to the different ECS elements, it is difficult to determine what needs to be built. These kinds of ambiguities could result in implementation differences, which if not caught early, could impact component testing. Minor inconsistencies in terminology identified in other requirements do not necessarily pose significant impacts to system development, however could cause discrepancies in development and test documentation.

- **Redundant requirement.** When adding new capabilities, one requirement may be changed and not the other. The missed requirements change may be coupled to test plans which can be used to determine the life-cycle impacts.

4.5.4 Overall ECS Requirements

This section discusses the overall impacts of the requirements problems identified earlier.

Issue Description	Issue Type	Potential Impacts
Broad scope.	Quality Testability	• Incomplete, or incorrect implementation of system features based on assumptions made to clarify missing details.
Incomplete requirement.	Quality	• Intended features are missing. • Inconsistent interfaces.

EXHIBIT 4-19: Potential Impacts of SDPS Requirements Analysis Issues

4.5.2 Flight Operations Segment Requirements

Overall, no significant problems resulted as a consequence of the analysis of FOS requirements. The identified problems involved either traceability or ambiguity issues and affected a small portion of the requirements. Yet it is beneficial to examine how these issues could affect system development activities and what steps can be implemented minimize the impact and benefit the program.

- **Impact of Traceability Issues -** Incomplete traceability information can result in functions not meeting all specifiedrequirements. Maintaining traceability data can assist the program by providing a means of obtaining additional information about a particular requirement. The user can clarify uncertainties by analyzing the origin of the requirement and associated lower level specifications. In addition, information on how a requirement relates to other similar functions can provide a complete system specification that can be useful during development and testing activities. A recommendation in this area is to formalize configuration control of traceability information in order to provide a single set of links that can be utilized by all participants during system development. This would be implemented by continuing to perform traceability analysis to add new linkages and refine existing ones.

- **Impact of Ambiguous Requirements -** Ambiguous requirements are most likely to affect system development activities by altering the amount of resources allocated to a certain function. Broad requirements and/or inconsistent terminology can translate into different interpretations by the developers thus creating the possibility of a faulty or incomplete functional implementation. This becomes even more critical in requirements addressing system level or interface functions. Ambiguous system requirements can create gray areas requiring additional use of resources during implementation. The additional resources may be needed to provide increased coordination and prevent duplication of effort and to closely manage interfaces between dependent functions. Ambiguous requirements would then need monitoring to ensure that the desired functionality is preserved as detailed requirements are generated. Again, a recommendation is to furnish requirement information to the program through tools such as RTM to assist in the understanding and interpretation of requirements by providing a source of additional clarification.

Issue Description	Issue Type	Potential Impacts
Missing peer linkages.	Traceability	• Difficult to perform impact assessment of Level 3 requirements changes. • Inconsistent interfaces within the SDPS, or between the SDPS and other ECS segments or external systems.
Missing peer requirement	Trace Quality	• Extraneous interface to another SDPS element or ECS segment. • Missing interface to another SDPS element or ECS segment. • Incompatible interfaces within the SDPS, or between the SDPS and other ECS segments or external systems. • Difficult to perform impact assessment of Level 3 requirements changes.
Inconsistent level of detail.	Quality	• Incomplete, or incorrect implementation of system features based on assumptions made to clarify missing details. • Inconsistent interfaces.
Inconsistent data flows.	Quality	• Incomplete or inconsistent interfaces between SDPS and other ECS segments, external systems or external facilities.
Inconsistent terminology or functionality	Quality Testability	• Varied, incomplete, or incorrect implementation of system features based on differing terminology or functionality. • Inconsistent system documentation (e.g., interface documents, test plans, user manuals, operations manuals) . • Quantitative acceptance test criteria based on incorrect assumptions.
Ambiguous wording.	Quality Testability	• Varied, incomplete, or incorrect implementation of system features based on assumptions required to clarify terms. • Inconsistent system documentation due to differing definitions. • Test plans/procedures and/or acceptance test criteria based on incorrect assumptions.
Questionable standards or guidelines.	Quality Testability	• Varied, incomplete, or incorrect implementation of system features based on evolutionary state of standard.
Redundant requirement.	Quality	• Multiple, and possibly different, implementations of similar features. • Excess software development and configuration management resulting in excess costs.

Req't ID	Link Count
651	100
1339	95
1416	49
1322	46
876	46
1252	42
892	41
1116	40
1158	39
1187	38
599	38

EXHIBIT 4-18: Partial List of Level 2 Volume 1 Requirements with Excessive Linkages

4.5 Analysis of Results

4.5.1 Science Data Processing Segment Requirements

Essential to the requirements analysis is the identification of the impacts that each type of problem, whether minor, moderate, or severe, could pose to successive ECS design, development, and implementation phases. The requirements analysis results for the SDPS, DADS, IMS, and PGS requirements in Section 4.3.2 show the kinds of problems found as well as the specific requirements exhibiting those problems. Exhibit 4-19 presents potential impacts associated with each of these problem areas.

Issue Description	Issue Type	Potential Impacts
Questionable Level 2 linkages.	Traceability	• Level 2 SDPS requirements are not completely satisfied. • Implementation of excess (unintended) functionality that could impact cost and schedule. • Difficult to perform impact assessment of Level 3 requirements changes. • Incomplete or incorrect requirements traces in test documentation.
Missing Level 2 linkages.	Traceability	• Implementation of excess (unintended) functionality that could impact cost and schedule. • Missing requirements traces in test documentation. • Difficult to perform impact assessment of Level 3 requirements changes.

4.4.4 Level 3 Communications and System Management Segment Requirements

This section describes the adverse impacts that the identified traceability and quality issues for CSMS may have in later life-cycle phases.

The potential impacts described in section 4.4.1 for the EOSD requirements apply with the following clarification:

- **Operationally Ambiguous System Capabilities** - Undefined support capabilities and inadequate data definitions increase the chances of delivering capabilities that do not meet the original intent.

4.4.5 Level 2 Requirements

This section describes potential problems with ESDIS Level 2 Volume 1 requirements.

Configuration Control of Traceability Data

The ECS Level 2 to Level 3 linkages are not currently under configuration control. If the linkage data is not configuration controlled, multiple and inconsistent versions of the linkages data may exist. These linkages are important to the ESDIS Project, system developers, and IV&V. The Project and HAIS needs these linkages to do impact analysis of proposed CCRs. HAIS also needs them to assure their system implementation is satisfying all applicable Level 2 requirements. The linkages are critically important to IV&V for many verification and validation activities.

Excessive Linkages

Many Level 2 Volume 1 requirements are linked to an excessively large number of Level 3 requirements. The benefits of having parent child linkages is reduced when large numbers of links are identified. Exhibit 4-18 lists some of the requirements with the highest numbers of linkages.

- **Questionable Derivation of Performance Specifications** - A number of Level 3 requirements included performance specifications that were derived from but not included in the Level 2 requirements. Requirement EOC-4210, which states that "the EOC shall process and output a single real-time emergency command within 500 milliseconds of receiving the request from the ICC,." is one example. This EOC requirement is linked to Level 2, Volume 1 requirement # 576 which states that ECS should not contribute more than 2.5 seconds to the end-to-end loop delay for real-time spacecraft commanding. It is clear that the EOC requirement falls within the allocated margins of the Level 2 requirement, but what is not evident is how the specific 500 millisecond figure was derived. Since the 500 milliseconds constitutes the EOC portion of the total ECS delay, the Level 2 requirement cannot be fully evaluated at this time because the only other element that has provided its portion of the delay has been the ICC (ICC-3360, 200 milliseconds). Additional analysis is needed to determine the validity of these derived specifications once the full allocation is known. The main question is whether these figures were arbitrarily derived or if they are the result of a formal analysis or study. This is one area where usage of the RTM tool can benefit the program since it provides a "clarification" fields for each requirement where the users can enter rationale and other reference information.

- **Incomplete Traceability to System Level Requirements** - The review of traceability information for FOS elements showed that in a number of occasions linkages were specified between Level 3 requirements and similar Level 2 requirements while linkages to Level 3 ECS system wide requirements were not provided. One example is requirement EOC-8220 which addresses fault isolation. This requirement has been linked to individual Level 2 requirements but no link was found to the ECS system level requirement EOSD-0800. EOSD-0800 addresses fault isolation and currently the only way to see the relationship between EOC-8220 and EOSD-0800 is through the parent Level 2 requirement. Yet this is one case where a peer link should exists and where it can be utilized to verify the stand-alone integrity of the Level 3 requirements and to ensure that system wide requirements are addressed within the elements.

- **Partial Interpretation of Compound and Broad Level 3 Requirements** - This is one area to be examined during the evaluation of Level 4 requirements. A number of the Level 3 requirements make general references to support certain functions or accommodate and provide interfaces to other elements. Of importance is to determine how the Level 4 requirements capture the intent and provide the required specification to proceed with the design.

- **Traceability of Level 3 to Level 4 requirements due to SDPS architecture shift**. A potential problem exist in the translation of Level 3 DADS, PGS, and IMS requirements, developed according to a "segment/element" approach, to the Level 4 requirements, which are being developed according to a "service oriented" approach. A consistent and complete traceability between Level 3 and Level 4 requirements is essential to ensure that functionality is not lost.

- **Loss of intended functionality as requirements are further decomposed**. As pointed out in Sections 4.3.2.1-3, there are several instances where the traceability linkages between the requirements are in question. In some cases (e.g., IMS-0590), it appears that some Level 2 functionality was omitted as the requirement was decomposed to Level 3. The magnitude of problems like these could increase significantly should the problems proliferate through successive phases of the design and implementation.

- **Inconsistent interfaces**. Although minor, if not resolved, inconsistencies found in the interfaces between SDPS elements and other ECS segments, external facilities, and external systems could severely impact overall system performance.

4.4.3 Level 3 Flight Operations Segment Requirements

In addition to the identified problems, the analysis of the Flight Operations Segment requirements highlighted several potential issues that might arise as development of the system progresses. The following is a summary of the major potential problems:

- **Functional Gaps Due to the Integration of EOC and ICC Requirements** - Prior to the analysis, there was discussion during the SDR about combining both the EOC and ICC requirements. Since such action had not yet been incorporated into the requirement documents, the IV&V team analyzed the requirements as they stood. During traceability analysis, it was noted that some requirements which were identical for both areas and which traced to the same parent were not linked as peers. It appears that currently specified peer linkages only address functions which require an interaction between the elements. It would be beneficial to expand the definition of peer linkages to include similar requirements derived from the same parent because such information can show the commonality between elements. For instance, if the EOC and ICC elements are integrated, the peer linkages could be used to determine what is already provided within the EOC and which unique ICC requirements need to be maintained or allocated to other functions.

- Another related issue is to ensure that any integration of EOC and ICC requirements accommodates non-U.S. external ICCs. The Level 3 requirements currently state that external non-U.S. ICCs shall interface in the same manner as U.S. ICCs but if the boundary between the EOC and U.S. ICCs becomes blurred it may be required to insert new requirements to address the international partners.

4.4 Potential Problems

4.4.1 Level 3 ECS System Level Requirements

This section describes the adverse impacts that the identified traceability and quality issues for the EOSD requirements may have in later life cycle phases.

- **Inconsistent Interface Design** - Missing peer-to-peer links can lead to implementation errors between the interfacing components. This may occur if the requirements for the interfacing components are inconsistent.

- **Operationally Unacceptable System Capabilities** - Inconsistent use of terminology creates the possibility of requirements misinterpretation, resulting in something being built that meets the requirements but does not meet the original intent.

- **Multiple Test Case Overlaps** - Peer-to-peer link deficiencies make it difficult to test threads involving multiple elements, segments or system components. If the linkages exist, then the path through the requirements specification tree for a particular test case can be found more quickly, reducing the number of test cases and test overlap.

- **Incomplete or Inaccurate Test Cases** - As a result of inaccurate, incomplete, and weak child/parent linkages, test cases may overachieve, underachieve or completelymiss a requirements intent.

- **Incomplete System Impacts** - The numerous weak child/parent linkages make it difficult to assess the life-cycle impacts of a particular requirements change.

- **Incomplete Requirement Changes** - When adding new capabilities or attempting to fix requirement deficiencies, the changes to the requirement specifications needed to incorporate the change may not be apparent. Unless peer-to-peer requirement relationships are established, redundant requirements increase the chances of only one requirement being fixed, resulting in breakage that may propagate throughout the life-cycle. Strong peer-to-peer and parent/child linkages increase the chances of making a change without breakage.

4.4.2 Level 3 Science Data Processing Segment Requirements

The objective of this section is to present additional problems that could arise in subsequent phases of the ECS life cycle based on the requirements analysis of the Science Data Processing Segment. The impacts of each type of problem identified in Sections 4.3.2.1-3 are discussed in Section 4.5.1. A summary of potential SDPS problems follows.

1599	3-19	The ECS shall be capable of expanding to accommodate data ingest and processing for U.S. instruments on international partner spacecraft without major redesign.	Section 3.8 EOSD0545, SDPS0170, PGS-1310, PGS-1270, PGS-1270, DADS1640, DADS3090, IMS-1800, SMC-0300, SMC-0310 ESN-0240, ESN-1207,
1602	3-17	The ECS shall have the capability to ingest documentation.	IMS-0490
1608	3-15	The ECS shall interface to external instrument control centers in accordance with an ECS standard interface.	Sections 6.1; 6.2; and 6.5.1.1

EXHIBIT 4-17: Recommended Links

Note that some of the candidate linkages are to general sections within the Level 3 requirements document. The current requirements linkage scheme only supports links between numbered requirements.

Weak Linkages

Many Level 2 to Level 3 linkages are weak, that is, there is no apparent reason for the linkages that can be discerned by looking at the text of the two linked requirements. These linkages should be recommended for deletion. These weak linkages are cited in the Level 3 to Level 2 linkage results given in Sections 4.3.1, 4.3.2, 4.3.3, and 4.3.4.

Other Problems

Requirement 576 has a reference to a Level 2 Volume requirement number ‘xxxx’. The ‘xxxx’ should be replaced with the correct requirement number.

> “576 The ECS shall contribute no more than 2.5 seconds to the end-to-end loop delay for ESDIS real-time commanding of the spacecraft in compliance with ESDIS Project Level 2 Requirements Volume 0 Overall ESDIS Project Requirements: requirement xxxx. .c.576 CH19”

The Level 2 Volume 1 Appendix A has not been updated for changes CH18 and CH19.

1577	3-4	The ECS shall support the ESDIS Project requirements relevant to ECS as specified in the ESDIS Project Level 2 Requirements Volume 0: Overall ESDIS Project Requirements.	Section 2.1.1 Applicable document 9
1579	3-4	ECS shall support the mission baseline identified in the ESDIS Project Level 2 Requirements Volume 0: Overall ESDIS Project Requirements.	Section 2.1.1 Applicable document 9
1586	3-20	The ECS shall provide sufficient processing capability to support algorithm integration and test concurrently with processing of new data.	PGS-1300 Sections 4.3.4; and 7.5.1.3, PGS-0600, PGS-0870
1596	3-28	The ECS shall maintain user audit trails for security and other accountability conditions.	EOSD3200 SMC-6315, SMC-6325
1597	3-28	The ECS shall provide the capability to account for resource utilization.	EOC-8150, EOC-8370, ICC-6080, ICC-6200, PGS-0370, Sections 7.5.2.2.1; and 7.5.3.1.11, DADS0890, DADS1470 Table 7-3 IMS-1650, IMS-1660 SMC-6360, SMC-6390, SMC-8840, SMC-8920
1598	3-14	The ECS shall be capable of expanding to accommodate the operation of U.S. instruments on international partner spacecraft without major redesign. ECS shall be able to accommodate growth (e.g., capacity) in all of its functions as well as the addition of new functions.	Sections 3.8; and 6.5.1.1 EOSD0545

L2 Req't	Pg. #	Requirement Text	Candidate Linkages
1396	3-6	All users shall access the EOSDIS ground segment through Information Management services at one of the system access nodes.	IMS-0030
1447	3-21	The ECS shall store data and related metadata in a standard, fully-defined format.	DADS3126 Sections 3.4.3; and 7.5.3.1.2 DADS0440 DADS0770 DADS0800 DADS1475 DADS3125
1448	3-21	The ECS shall provide quality information with the spacecraft parameters prior to archiving.	EOC-5050 ICC-4070 Section 7.2
1458	3-29	The ECS shall be implemented in a sequence of versions, each of which shall incorporate improvements and modifications based upon user experience with preceding versions.	Sections 3.2.1; and 7.5.3.2.1 ECS SOW SDPS 0085
1461	3-29	The transition from one version to another shall be contingent upon user acceptance of the new version.	ECS SOW
1462	3-29	The transition shall be accomplished with minimal interruption or degradation of services to EOSDIS users.	ECS SOW Section 7.5.3.2.1
1564	3-29	The ECS shall ingest from the external instrument control centers instrument operations history, command histories, engineering and housekeeping data and associated metadata.	Sections 6.5.1.1.6; 6.5.1.1.7; and 6.5.2.2.1.6 Tables 6-2 and 7-2 ICC-4800, ICC-4810, ICC-4820, ICC-6200
1565	3-18	The ECS shall generate prototype data products, but such processing shall not interfere with standard data product generation.	SDPS0030 Sections 7.5.1.1; and 7.5.1.4c

L2 Req't	Pg. #	Requirement Text
509	3-3	The ECS shall maximize the scientific return from the EOS program with the most economical use of resources throughout the life of the program.
518	3-3	The ECS shall maximize opportunities for commonality within the system.
1367	3-16	The ECS shall generate and validate command sequences to control the operation of the x-band direct down link.
1570	3-25	The ECS shall have available for user access metadata information for non-EOS data products it has received and retained according to established EOSDIS standards.
1573	3-28	The ECS shall support verification of all external interfaces (e.g., EDOS).
1592	3-27	The ECS shall receive management information from ECOM and EDOS.
1603	3-7	The ECS shall take advantage of local user workstations to optimize system performance.

EXHIBIT 4-16: Childless Level 2 Volume 1 Requirements

For 17 of the 24 unlinked requirements, candidate linkages to Level 3 child requirement(s) were identified. Exhibit 4-17 lists these requirements and the candidate linkages.

4.3.5.1 Traceability to Level 1 Requirements

Traceability data between EOS Level 1 and ESDIS Level 2 Volume 1 requirements was obtained from the Mission to Planet Earth Office. The analysis revealed that many Level 2 Volume 1 requirements do not have linkages to the Level 1 EOS Project Plan. In total, 40% of the Level 2 Volume 1 requirements, 107 out of 268 requirements, were not linked to Level 1 requirements. The absence of linkages does not necessarily indicate that these are orphan requirements. Additional work is needed to identify the linkages and verify that these Level 2 requirements have Level 1 parents. Two minor traceability problems were found which involved questionable or incomplete traceability to Level 1 requirements. Exhibit 4-15 summarizes these traceability problems.

Issue Description	Number of Affected Requirements
No Level 1 linkages identified	107
Incomplete Level 1 linkages	1
Questionable Level 1 linkages	1

EXHIBIT 4-15: Summary of Level 2 to Level 1 Traceability Issues

4.3.5.2 Traceability to Level 3 Requirements

Unlinked Requirements

The linkages between the ESDIS Level 2 Volume 1 requirements and ECS Level 3 requirements were examined to find unlinked Level 2 requirements. A total of 24 unlinked requirements were found. A preliminary search of the ECS level 3 requirements was made to find candidate child requirements. Suitable Level 3 child requirements could not be found for 7 of the 24. Exhibit 4-16 lists the 7 childless requirements from ESDIS Level 2 Volume 1.

- *Questionable Level 2 linkages.* Multiple linkages to Level 2 requirements exist for several SMC requirements, thus obscuring the origin from which these requirements were derived.

Quality Issues

- *Inconsistent terminology or functionality.* Many interfaces are described using the terms "attributes" and "directives", with no hint at the type of data to be sent. These data descriptions are inconsistent with the level of detail found in the Level 3 specification for other elements. For instance, the DADS context diagram is supplemented with a detailed table describing the data source, data destination, and data content. The term "element" is used inconsistently. LSM is described as an element which manages other ECS elements. In fact, LSM is a part of the SMC element distributed across the ECS elements.

- *Broad scope.* An interface between system components and elements cannot be established for broadly defined functions, such as the support of ground event scheduling, resolution services, and training certification.

Issue Description	Issue Type	Associated Requirements
Missing peer linkages.	Traceability	SMC-1000, SMC-1310, SMC-1330, SMC-2210, SMC-2300, SMC-2320,SMC-2510, SMC-2530, SMC-2540, SMC-2540, SMC-2600, SMC-2610, SMC-2620, SMC-3300, SMC-3310, SMC-5320, SMC-6300, SMC-6400,SMC-6410, SMC-8890, SMC-8920
Questionable Level 2 linkages.	Traceability	SMC-2420, SMC-2600, SMC-4305, SMC-7310, SMC-7320, SMC-8700, SMC-8730, SMC-8750, SMC-8770, SMC-8790, SMC-8800, SMC-8820, SMC-8840, SMC-8841, SMC-8860, SMC-8880, SMC-8890, SMC-8920, SMC-2605, SMC-8305, SMC-8705
Inconsistent terminology or functionality.	Quality	SMC-1330, SMC-2520, SMC-3421
Broad scope.	Quality	SMC-1300, SMC-1330, SMC-1500,SMC-2400, SMC-2410, SMC-2420,SMC-2430, SMC-2450, SMC-2510

EXHIBIT 4-14: Summary of SMC Issues

4.3.5 Level 2 Requirements

This section describes identified traceability problems associate with the ECS portions of the EOS Level 1 requirements, the ESDIS Level 2 Volume 1 requirements and the ECS Level 3 requirements. Traceability problems between Level 3 and Level 2 are discussed in the ECS element sections within section 4.3.

- *Questionable Level 2 linkages.* A small number of links to Level 2 requirements are weak, incomplete, or inaccurate. Weak linkages, such as these, have the potential to obscure the origin of a particular Level 3 requirement, as well as make it difficult to gauge to what extent the ESN interacts with a particular element in providing network services. For instance, ESN-0010 and ESN-1181 describe the need for an ESN Bulletin Board Service. It is not clear how (through element reporting, ESN reporting or both) the bulletin board is populated or to what extent (element application availability status, connection availability status, etc.).

Quality Issues

- *Redundant Requirements.* ESN-0240 states a generic need for the expandability of communication resources, whereas ESN-1207 describes to what extent the communication services should be expandable. The latter requirement more precisely specifies the quantity of growth required, whereas the former is more ambiguous and open-ended.

Issue Description	Issue Type	Associated Requirements
Missing peer linkages.	Traceability	ESN-0010, ESN-0080, ESN-0250, ESN-0280, ESN-0290, ESN-0640, ESN-0815, ESN-0830, ESN-0900, ESN-1060, ESN-1181, ESN-1206
Questionable Level 2 linkages.	Traceability	ESN-0005
Redundant requirements.	Quality	ESN-0240, ESN-1207

EXHIBIT 4-13: Summary of ESN Issues

4.3.4.2 System Management Center Requirements (SMC)

The SMC section consists of 145 functional and performance requirements. Exhibit 4-14 summarizes the issues found; detailed descriptions and recommendations for each of these requirements are in Appendix C, D, and E. Traceability and quality issues identified are summarized as follows:

Traceability Issues

- *Missing peer linkages.* Peer linkages were not specified for any of the 145 ECS system level requirements

Testability Issues

- *Ambiguous wording.* Assumptions as to the meaning of these words or phrases are required to define a test approach and/or quantitative acceptance criteria.

  Broad scope. The requirement is too general. Due to missing details, assumptions are required to formulate a test approach and/or quantitative acceptance criteria.

Issue Description	Issue Type	Affected Requirements
Missing Peer Linkages.	Traceability	ICC-1050, ICC-1160, ICC-2015, ICC-2055, ICC-4800, ICC-4810, ICC-4820
Questionable Level 2 Linkages.	Traceability	ICC-2010, ICC-3020, ICC-4090, ICC-4470, ICC-4830
Ambiguous wording.	Quality	ICC-1082, ICC-4110, ICC-4480
	Testability	ICC-4110
Broad scope.	Quality	ICC-0070, ICC-2120, ICC-4540, ICC-4545, ICC-6020, ICC-6600
	Testability	ICC-0070, ICC-4545, ICC-6020, ICC-6600

EXHIBIT 4-12: Summary of ICC Issues

4.3.4 Level 3 Communications and System Management Segment Requirements

The CSMS segment is comprised of two elements, the ESN and the SMC, which provide the communication and system management capabilities that allow the ECS to operate as an integrated information management system. Highlights of the major CSMS requirement issues are described in the subsections that follow.

4.3.4.1 EOS Science Network Requirements (ESN)

The ESN section consists of 66 functional and performance requirements. Exhibit 4-13 summarizes the issues found; detailed descriptions and recommendations for each of these requirements are in Appendix C, D, and E. Traceability and quality issues identified are summarized as follows:

Traceability Issues

- *Missing peer linkages.* Peer linkages were not specified for any of the 66 ECS system level requirements

Traceability Issues

- *Missing peer linkages.* Peer linkages were not indicated for several requirements. Requirements ICC-1050, ICC-1160, and ICC-2055 did not specify links to related DMZ requirements. Requirement ICC-2015 did not specify a link to a related EOC Planning and Scheduling requirements. Requirements ICC-4800, ICC-4810, and ICC-4820 were missing peer linkages to DADS requirements.

- *Questionable Level 2 linkages*. The completeness and/or accuracy of Level 2 linkages was questionable in several requirements.

Quality Issues

- *Ambiguous wording*. The general purpose of the requirement is understood, however, in the context given, the word or phrase could yield more than one interpretation. The term "Conformity Check" for DAR is ambiguous in ICC-1082. It is not clear what was involved in performing this verification.

- *Broad scope*. Several requirements are stated in broad terms require additional detail for clarification. Example issues include the following:

  ICC-0070: This requirement to accommodate software and hardware provided by the Instrument Team was is broad and needs a narrower definition and reference to an interface standard.

  ICC-2120: Examples are needed to clarify the typical activities that are to be supported (i.e., calibration, etc.).

  ICC-4545: Criteria is needed for a capability to recommend instrument reconfigurations. It was not clear from the requirement what action or event would trigger these recommendations.

  ICC-6020: Clarification of the capability of ICC to establish its configuration is needed. This requirement was ambiguous and needs additional information to define its scope.

  ICC-6600: Clarification of performance criteria for the system to respond within 0.5 seconds is needed. It is not clear from the requirement if the response is associated to obtaining a prompt or executing a certain function. Also the system loading assumed for the response should be clearly stated to prevent assumptions.

obtaining a prompt or executing a certain function. Also the system loading assumed for the response should be clearly stated to prevent assumptions.

Testability Issues

- *Inconsistent terminology or functionality*. Varying terminology requires assumptions in defining a test approach and/or quantitative acceptance criteria.

- *Ambiguous wording*. Assumptions as to the meaning of these words or phrases are required to define a test approach and/or quantitative acceptance criteria.

- *Broad scope*. The requirement is too general. Due to missing details, assumptions are required to formulate a test approach and/or quantitative acceptance criteria.

Issue Description	Issue Type	Associated Requirements
Missing Peer Linkages	Traceability	EOC-4168
Questionable Level 2 Linkages	Traceability	EOC-2180, EOC-2190, EOC-2200, EOC-2250, EOC-2350, EOC-3080, EOC-3160, EOC-4005, EOC-4060, EOC-4100, EOC-4130, EOC-4160, EOC-4168, EOC-5110, EOC-5200, EOC-6080, EOC-6150, EOC-6195, EOC-7115, EOC-7116, EOC-7125, EOC-7140, EOC-7150, EOC-7160, EOC-8372, EOC-8380
Inconsistent terminology or functionality.	Quality	EOC-2020
	Testability	EOC-2020
Ambiguous wording.	Quality	EOC-5105, EOC-8090
	Testability	EOC-5105, EOC-8090
Broad scope	Quality	EOC-2045, EOC-3225, EOC-3226, EOC-4015, EOC-4018, EOC-5187, EOC-6135, EOC-9110
	Testability	EOC-2045, EOC-3225, EOC-3226, EOC-4015, EOC-4018, EOC-5187, EOC-6135, EOC-9110

EXHIBIT 4-11: Summary of EOC Issues

4.3.3.3 Instrument Control Center Requirements (ICC)

The ICC requirements apply to all the services associated with this function, including the IST requirements. The following are highlights of the identified issues for this element. Exhibit 4-12 summarizes the problems found in this area.

Traceability Issues

- *Missing peer linkages.* Traceability information did not provide a peer link to ICC requirements for the EOC requirement stating that command notification messages be provided to the ICC. (EOC-4168)

Quality Issues

- *Inconsistent terminology or functionality.*. The definition for "Long Term Spacecraft Operations Plan" contained within the FOS section differs from what is stated in the Appendices. (EOC-2020)

- *Ambiguous wording.* The general purpose of the requirement is understood, however, in the context given, the word or phrase could yield more than one interpretation. Example issues include the following:

  EOC-5105: The purpose for requiring multiple sets of limits needs to be defined. It is not clear from the requirement what the different limit sets would be used and to what extent.

  EOC-8090: Clarification of the capability of EOC to establish its configuration is needed. This requirement was ambiguous and needs additional information to define its scope.

- *Broad scope.* Several requirements are stated in broad terms require additional detail for clarification. Example issues include the following:

  EOC-2045: The phrase "Common Set of Capabilities" is broadly stated. Examples of typical desired capabilities can clarify the scope of this requirement.

  EOC-3225: Number of simultaneous TOO activities to be supported is unclear. Since resources will be limited, it is necessary to know how many simultaneous Targets of Opportunity the system should be able or expected to support.

  EOC-4015: Validation process for commands may need additional clarification. The scope of command validation needs to be clearly define in order to focus development effort.

  EOC-6135: Criteria is needed for capability to recommend spacecraft reconfigurations. It was not clear from the requirement what action or event would trigger these recommendations.

  EOC-9110: Clarification of performance criteria for the system to respond within 0.5 seconds is needed. It is not clear from the requirement if the response is associated to

EOS Operation Center (EOC) requirements, and Instrument Control Center (ICC) requirements. The ICC segment also includes requirements for the Instrument Support Terminal (IST) sub-element. In general, the majority of the problems centered around traceability and quality issues. The following is an overall summary of the issues for the entire segment by type.

4.3.3.1 FOS Segment Level Requirements (FOS)

The FOS segment level requirements apply to all the elements associated with this function. The following are highlights of the identified issues for this element. Exhibit 4-10 summarizes the problems found in this area.

Traceability Issues

- *Questionable Level 2 linkages*. The Level 2 links provided for the FOS requirement addressing the adaptation of a general purpose scheduling interface for communicating planning and scheduling information are questionable. (FOS-0030)

Quality Issues

- *Broad scope*. It is not clear from the Level 3 requirement if the system is required to provide the full complement of FOS capabilities while in the training mode of operations. The scope of this requirement needs further definition to indicate which functions are needed and thus allocate the proper amount of resources. (FOS-0020)

Testability Issues

- *Broad scope*. The broad scope of FOS-0020 affects the development of acceptance test criteria for this requirement.

Issue Description	Issue Type	Affected Requirements
Questionable Level 2 linkages.	Traceability	FOS-0030
Broad scope.	Quality	FOS-0020
	Testability	FOS-0020

EXHIBIT 4-10: Summary of FOS Segment Level Issues

4.3.3.2 EOS Operations Center Requirements (EOC)

The EOC requirements apply to all the services associated with this function. The following are highlights of the identified issues for this element. Exhibit 4-11 summarizes the problems found in this area.

- *Inconsistent level of detail.* The level of detail of the requirement is inconsistent with related (i.e., peer) ECS or non-ECS requirements.

- *Redundant requirement.* Functionality specified in requirement is redundant with this or another element/segment.

Testability Issues

- *Ambiguous wording.* Assumptions as to the meaning of these words or phrases are required to define a test approach and/or quantitative acceptance criteria.

- *Broad scope.* The requirement is too general. Due to missing details, assumptions are required to formulate a test approach and/or quantitative acceptance criteria.

Issue Description	Issue Type	Associated Requirements
Missing Level 2 linkages.	Traceability	PGS-0420, PGS-0430
Questionable Level 2 linkages.	Traceability	PGS-0290, PGS-0455, PGS-0456, PGS-0458, PGS-0510, PGS-0600, PGS-1015, PGS-1080, PGS-1090, PGS-1250, PGS-1260
Inconsistent data flows.	Quality	PGS-0140, PGS-0150, PGS-0160, PGS-0640, PGS-0960
Inconsistent terminology or functionality.	Quality	PGS-0150, PGS-0160, PGS-0180, PGS-0285, PGS-1030
Ambiguous wording.	Quality	PGS-0210, PGS-0285, PGS-0295, PGS-0456, PGS-0650, PGS-0910, PGS-0970, PGS-1210, PGS-1230
	Testability	PGS-0285, PGS-0456, PGS-0650, PGS-0910, PGS-0970, PGS-1210
Broad scope.	Quality	PGS-0380, PGS-0540, PGS-0550, PGS-0650, PGS-0910, PGS-1150, PGS-1170, PGS-1220
	Testability	PGS-0540, PGS-0550, PGS-0650, PGS-0910
Inconsistent level of detail.	Quality	PGS-0160, PGS-0285
Redundant requirement.	Quality	PGS-0420, PGS-0490

EXHIBIT 4-9: Summary of PGS Issues

4.3.3 Level 3 Flight Operations Segment Requirements

The review of the Functional and Performance Requirement Specifications for the Flight Operations Segment involved analyzing three distinct areas: overall FOS segment requirements,

4.3.2.4 Product Generation System Requirements (PGS)

The PGS section consists of 104 functional, performance, and application programming interface (API) requirements. The functional requirements address the four basic services provided by PGS, namely, scheduling, product generation, algorithm test and integration, and product management. Exhibit 4-9 summarizes the issues found; detailed descriptions and recommendations for each of these requirements are in Appendix C, D and E. Traceability, quality, and testability issues, most of them minor, were identified for 35 requirements and are summarized as follows:

Traceability Issues

- *Missing peer linkages.* Peer links are not specified for any of the 104 PGS requirements.

- *Questionable Level 2 linkages.* In most cases, the specified links are incomplete (i.e., additional links are needed), and in one case the links are over specified (i.e., one or more links are not applicable).

- *Missing Level 3 Linkages.* All requirements in this section have at least one link to a Level 2 requirement, except for PGS-0420 and PGS-0430.

Quality Issues

- *Inconsistent data flows.* A data transfer is specified in the requirement that is not specified either the Conceptual PGS Context Diagram (Figure 7-3) or the Conceptual PGS Data Flows (Table 7-1), or a data transfer is specified in either Figure 7-3 or Table 7-1 that is not satisfied by any PGS requirements.

- *Inconsistent terminology or functionality.* The terminology used, or the functionality indicated in the requirement is inconsistent with other ECS requirements and/or other sections of the ECS F&PRs.

- *Ambiguous wording.* The general purpose of the requirement is understood, however, in the context given, the word or phrase could yield more than one interpretation.

- *Broad scope*. The requirement is too general. Due to missing details, either the scope or purpose of the requirement is not clear.

- *Questionable standards or guidelines.* Standard formatting convention specified in the requirement is not defined.

Quality Issues

- *Inconsistent terminology or functionality.* The terminology used, or the functionality indicated in the requirement is inconsistent with other ECS requirements and/or other sections of the ECS F&PRs.

- *Ambiguous wording.* The general purpose of the requirement is understood, however, in the context given, the word or phrase could yield more than one interpretation.

- *Broad scope.* The requirement is too general. Due to missing details, either the scope or purpose of the requirement is not clear.

- *Inconsistent level of detail.* The level of detail of the requirement is inconsistent with related (i.e., peer) ECS or non-ECS requirements.

- *Incomplete requirement.* Minor functional capabilities may have been omitted.

Testability Issues

- *Broad scope.* The requirement is too general. Due to missing details, assumptions are required to formulate a test approach and/or quantitative acceptance criteria.

Issue Description	**Issue Type**	**Associated Requirements**
Questionable Level 2 linkages.	Traceability	IMS-0590, IMS-0800, IMS-0960
Inconsistent terminology or functionality.	Quality	IMS-0910, IMS-1010, IMS-1030, IMS-1060, IMS-1210, IMS-1450, IMS-1650, IMS-1700
Ambiguous wording.	Quality	IMS-0180, IMS-0270, IMS-0440, IMS-1600
Broad scope.	Quality	IMS-0480, IMS-0570, IMS-0600, IMS-0640, IMS-0690, IMS-1105
	Testability	IMS-0570, IMS-1105
Inconsistent level of detail.	Quality	IMS-0480
Incomplete requirement.	Quality	IMS-0490, IMS-0560, IMS-0630, IMS-0730, IMS-0740, IMS-1000, IMS-1050, IMS-1070, IMS-1160, IMS-1470, IMS-1510, IMS-550, IMS-1720

EXHIBIT 4-8: Summary of IMS Issues

Issue Description	Issue Type	Associated Requirements
Questionable Level 2 linkages.	Traceability	DADS1520, DADS1640, DADS2060, DADS3010, DADS3090
Inconsistent data flows.	Quality	DADS0120, DADS0150, DADS0160, DADS0180, DADS2330, DADS2340, DADS2345, DADS2360, DADS2370, DADS2380, DADS2390, DADS2470
Inconsistent terminology or functionality.	Quality	DADS0140, DADS1210, DADS1640, DADS2120
Inconsistent level of detail.	Quality	DADS1950, DADS1960, DADS1970, DADS2060, DADS2070
Missing peer requirement.	Quality	DADS2230
Broad scope.	Quality	DADS1340
Ambiguous wording.	Quality	DADS0430, DADS0610, DADS0680, DADS2170, DADS2480, DADS2910
	Testability	DADS0430, DADS0610, DADS0680, DADS2480, DADS2910, DADS1640
Questionable standards or guidelines.	Quality	DADS1700
	Testability	DADS1700

EXHIBIT 4-7: Summary of DADS Issues

4.3.2.3 Information Management System Requirements (IMS)

The IMS section consists of 193 functional, performance, and application programming interface (API) requirements that address 11 major service areas. Exhibit 4-8 summarizes the issues found; detailed descriptions and recommendations for each of these requirements are in Appendix C, D, and E. Traceability, quality, and testability issues, most of them minor, were identified for 33 requirements and are summarized as follows:

Traceability Issues

- *Missing peer linkages.* Peer links are not specified for any of the 193 IMS requirements.

- *Questionable Level 2 linkages.* In some cases, the specified links are incomplete (i.e., the functionality stated in the Level 2 requirement is not completely carried down to Level 3), and in other cases the specified links are incorrect (i.e., a more appropriate link could be found).

Quality Issues

- *Inconsistent data flows.* A data transfer is specified in the requirement that is not specified either the Conceptual DADS Context Diagram (Figure 7-4) or the Conceptual DADS Data Flows (Table 7-2), or a data transfer is specified in either Figure 7-4 or Table 7-2 that is not satisfied by any DADS requirements.

- *Inconsistent terminology or functionality.* The terminology used, or the functionality indicated in the requirement is inconsistent with other ECS requirements and/or other sections of the ECS F&PRs.

- *Ambiguous wording.* The general purpose of the requirement is understood, however, in the context given, the word or phrase could yield more than one interpretation.

- *Broad scope.* The requirement is too general. Due to missing details, either the scope or purpose of the requirement is not clear.

- *Questionable standards or guidelines.* Due to the dependence on an evolving standard, the requirement is undefined.

- *Inconsistent level of detail.* The level of detail of the requirement is inconsistent with related (i.e., peer) ECS or non-ECS requirements.

- *Missing peer requirement.* The requirement specifies an interface to another element/segment; a corresponding (i.e., peer) requirement for that element/segment could not be found in the Level 3 F&PRs.

Testability Issues

- *Inconsistent terminology or functionality.* The requirement references another section of the F&PRs which contains volume estimates, however, sufficient information was not found to support the requirement. Additional detail is needed to derive quantitative acceptance criteria.

- *Ambiguous wording.* Assumptions as to the meaning of these words or phrases are required to define a test approach and/or quantitative acceptance criteria.

- *Questionable standards or guidelines.* Adherence to specific standards are difficult to test due to the standard being in an evolutionary stage.

- *Missing Level 2 linkages*. All requirements in this section have at least one link to a Level 2 requirement, except for SDPS0085.

Quality Issues

- *Ambiguous wording*. The general purpose of the requirement is understood, however, in the context given, the word or phrase could yield more than one interpretation.

- *Broad Scope*. The requirement is too general. Due to missing details, either the scope or purpose of the requirement is not clear.

Issue Description	Issue Type	Associated Requirements
Missing Level 2 linkages.	Traceability	SDPS0085
Questionable Level 2 linkages.	Traceability	SDPS0040
Ambiguous wording.	Quality	SDPS0050, SDPS0080, SDPS0090, SDPS0095
Broad scope.	Quality	SDPS0120, SDPS0140, SDPS0170

EXHIBIT 4-6: Summary of SDPS Segment Level Issues

4.3.2.2 Data Archive and Distribution System Requirements (DADS)

The DADS section consists of 196 functional, performance, and application programming interface (API) requirements. The functional requirements address the five major services at each DADS, namely, data ingest, data archive, orders/requests processing, system management, and information distribution. Exhibit 4-7 summarizes the issues found; detailed descriptions and recommendations for each of these requirements are in Appendix C, D, and E. Traceability, quality, and testability issues, most of them minor, were identified for 33 requirements and are summarized as follows:

Traceability Issues

- *Missing peer linkages.* Peer links are not specified for any of the 196 DADS requirements.

- *Questionable Level 2 linkages.* In some cases, the specified links are incomplete (i.e., additional links are needed), and in other cases the specified links are incorrect (i.e., a more appropriate link could be found).

Issue Description	Issue Type	Associated Requirements
Missing peer linkages.	Traceability	EOSD0010, EOSD0015, EOSD0020, EOSD0025, EOSD0030, EOSD0040, EOSD1000, EOSD1010, EOSD1030, EOSD1040, EOSD1050, EOSD1060, EOSD1070, EOSD1080, EOSD1140, EOSD1480, EOSD1490, EOSD1500, EOSD1680, EOSD1690, EOSD1695, EOSD5000, EOSD5010, EOSD5100, EOSD5200, EOSD5210, EOSD5300, EOSD5310
Questionable Level 2 linkages.	Traceability	EOSD1608, EOSD1740, EOSD1750, EOSD1760, EOSD1770, EOSD4036, EOSD4100,
Ambiguous wording.	Quality	EOSD0540, EOSD0545, EOSD0560, EOSD1705, EOSD1750, EOSD2480, EOSD2550
Redundant requirements.	Quality	EOSD3710, EOSD3800

EXHIBIT 4-5: Summary of EOSD System Level Issues

4.3.2 Level 3 Science Data Processing Segment Requirements

Requirements for the Science Data Processing Segment (SDPS) are divided into the following areas: segment level; Data Archive and Distribution System; Information Management System; and Product Generation System. They are prefaced with “SDPS”, “DADS”, “IMS”, and “PGS”, respectively. The following sections present the traceability, quality, and testability issues identified for each of these areas.

4.3.2.1 Segment Level Requirements (SDPS)

The segment level SDPS area consists of 29 functional, performance, and interface requirements. Exhibit 4-6 summarizes the issues found; detailed descriptions and recommendations for each of these requirements are in Appendix C and Appendix E. Traceability and quality issues, most of them minor, were identified for nine requirements and are summarized as follows:

Traceability Issues

- *Missing peer linkages.* Peer links are not specified for any of the 29 SDPS requirements.

- *Questionable Level 2 linkages.* In SDPS0050, it is questionable whether the Level 2 requirement specified is the appropriate link.

4.3 Identified Problems

This section discusses the problems identified as a result of the ECS Level 2 and Level 3 requirements analyses.

4.3.1 Level 3 ECS System Level Requirements

The ECS is comprised of the Flight Operations Segment (FOS), the Science Data Processing Segment (SDPS), and the Communications and System Management Segment (CSMS), which collectively provide the services to command and control spacecraft instruments and to manage the earth science data repository. The ECS system level requirements are those requirements that are common to all three ECS segments, and are prefaced with "EOSD". Quality and traceability issues identified for these requirements follows. The types of issues found and the associated requirement references are summarized in Exhibit 4-5.

Traceability Issues

- *Missing peer linkages.* Peer linkages were not specified for any of the 125 ECS system level requirements

- *Questionable Level 2 linkages.* A small number of links to Level 2 requirements are weak, incomplete, or inaccurate. Weak linkages, such as these, have the potential to obscure the origin of a particular Level 3 requirement.

Quality Issues

- *Ambiguous wording.* Use of words or phrases out of context, such as "DAAC", could lead to interpretation issues. For instance, in one context DAAC refers to *existing* data center facilities performing data archiving, retrieving, and distribution. In another context, DAAC refers to the *elements being built* under the EOSDIS contract and deployed to the DAAC data centers. Although the two are related, they do have different meanings, since the capabilities of the two types of DAACs are different.

- *Redundant requirements.* EOSD3710 and EOSD3800 are redundant RMA requirements. EOSD3710 describes a FOS requirement for having no single point of failure for real-time operations of the spacecraft and instruments. The intent of EOS3710 is included in the EOSD3800 requirement, which describes the availability requirement of .9998 for similar real-time operations.

4.2 Problem Classification

Traceability, quality, and testability problems found during the ECS requirements analysis are grouped into the following categories:

Questionable Level 2 linkages. Links to Level 2 requirements are incorrect or incomplete. Links may be over-specified, under-specified, or incorrectly specified.

Missing Level 2 linkages. Links to Level 2 requirements are not specified.

Missing peer linkages. Links to related Level 3 requirements (i.e., peer) are not specified.

Missing peer requirement. Related Level 3 requirement (i.e., peer) does not exist.

Inconsistent level of detail. Level of detail is inconsistent with related Level 3 (i.e., peer) requirements.

Inconsistent data flows. Information flows specified in the requirement are inconsistent with context diagrams and/or data definition tables.

Inconsistent terminology or functionality. Terminology used, or functionality indicated is inconsistent with other ECS requirements and/or other sections of the F&PRs.

Ambiguous wording. Words or phrases are unclear or undefined, and could yield more than one interpretation.

Questionable standards or guidelines. Requirement mandates use of an evolving standard.

Redundant requirement. Functionality specified in the requirement is redundant with another Level 3 requirement.

Broad scope. The requirement is too general. Due to missing details, either the scope or purpose of the requirement is unclear.

Incomplete requirement. Minor functional capabilities are missing.

Lessons learned. Requirements are missing at Level 2 and Level 3 to address several lessons learned from other GSFC data and information systems.

Exhibits 4-2, 4-3 and 4-4 illustrate the requirements analysis metrics for traceability, quality and testability.

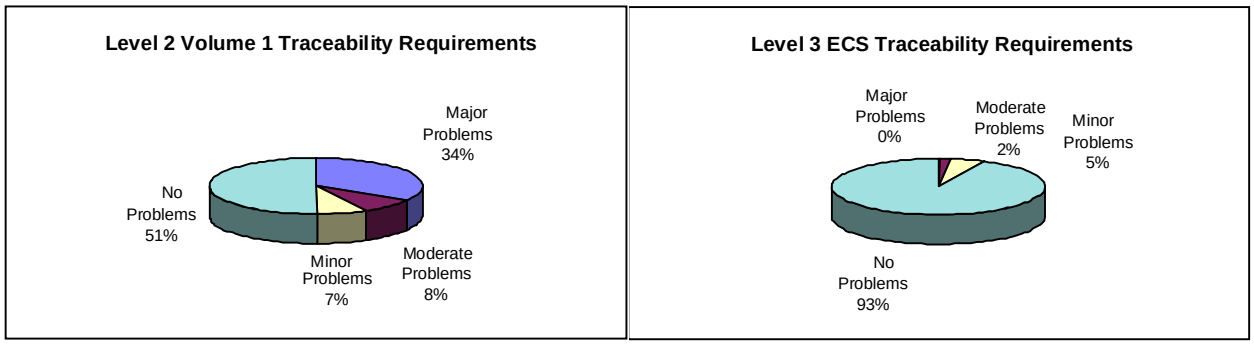


EXHIBIT 4-2: Metrics for Traceability

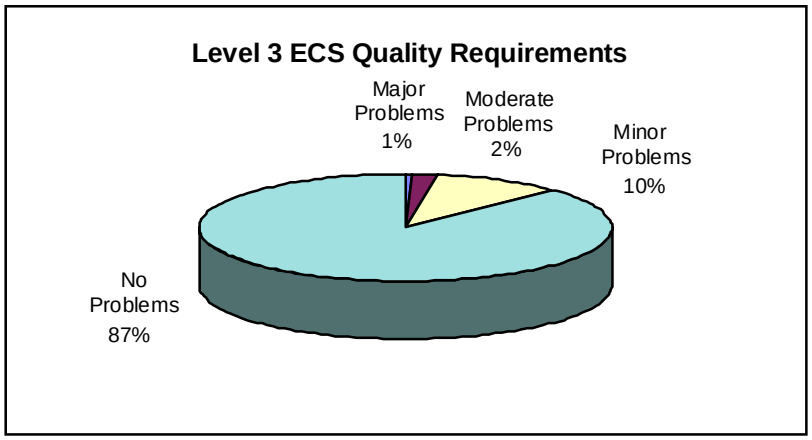


EXHIBIT 4-3: Metrics for Quality

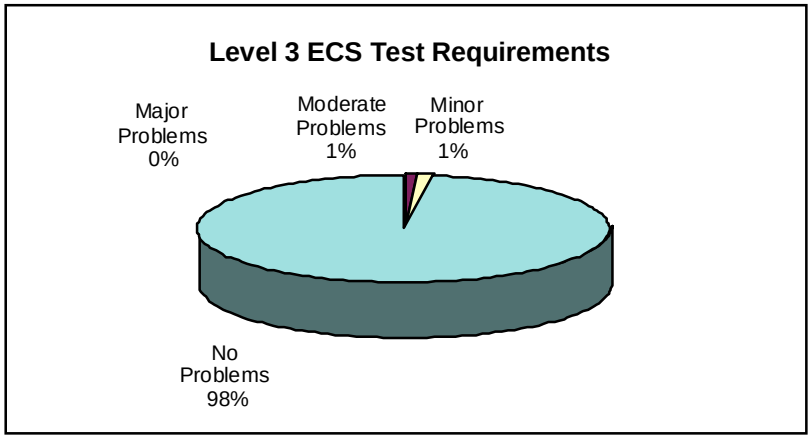


EXHIBIT 4-4: Metrics for Testability

4.0 RESULTS

This section describes the results of the requirements analysis. Problem details, requirement-by-requirement, are described in Appendices C (major problems), D (moderate problems), and E (minor problems). Appendix F contains the associated analysis rationale text. Appendix B is the road map into the appendices and should be understood prior to referencing them. The formats of Appendices C, D, E, and F closely parallel the actual structure of the ARDB.

4.1 Overview of Results

Exhibit 4-1 provides a summary of the ECS Level 3 requirements analysis results by system area.

Level 2 Volume 1	Total No	Major Problems			Moderate Problems			Minor Problems			No Problems		
Requirements	of Rqts	Trace	Qual	Test	Trace	Qual	Test	Trace	Qual	Test	Trace	Qual	Test
Vol 1 S-3.1.1 Gen'l/etc	69	29	n/a	n/a	1	n/a	n/a	8	n/a	n/a	31	n/a	n/a
Vol 1 S-3.1.2 Func/etc.	183	58	n/a	n/a	20	n/a	n/a	12	n/a	n/a	93	n/a	n/a
Vol 1 S-3.2 Evolve/etc.	16	4	n/a	n/a	1	n/a	n/a		n/a	n/a	11	n/a	n/a
Level 2 Vol 1 Total	268	91	n/a	n/a	22	n/a	n/a	20	n/a	n/a	135	n/a	n/a
Level 3 ECS	**Total No**	**Major Problems**			**Moderate Problems**			**Minor Problems**			**No Problems**		
Requirements	**of Rqts**	**Trace**	**Qual**	**Test**	**Trace**	**Qual**	**Test**	**Trace**	**Qual**	**Test**	**Trace**	**Qual**	**Test**
ECS EOSD (Sys Lvl)	125				2			5	28		118	97	125
ECS SDPS DADS	196				2	4	1	3	26	7	191	166	188
ECS SDPS IMS	193				1	3		2	28	2	190	162	191
ECS SDPS PGS	104	2				2	2	11	23	6	91	79	96
ECS SDPS SDPS	29	1						1	7		27	22	29
ECS FOS EOC	176				1	8	6	25	4	1	150	164	169
ECS FOS FOS	6				1				1	1	5	5	5
ECS FOS ICC	211				11	5	3	1	4		199	202	208
ECS CSMS ESN	66				1				1		65	65	66
ECS CSMS SMC	145		7		3	3		18	1		124	134	145
Level 3 ECS Total	1251	3	7	0	22	25	12	66	123	17	1160	1096	1222
n/a: Not Analyzed (Out of scope of this analysis)													
Note: Row values may not sum to total number of requirements since a requirement can exhibit multiple problem levels													

EXHIBIT 4-1: Requirements Analysis Summary

TRACEABILITY DATA	SOURCE
Level 1 to Level 2	SEIMSS/MTPE
Level 2 to Level 3	HAIS

EXHIBIT 3-5: Sources of Requirement Linkages

for it's capability to trace requirements back to parent documents, utilizing the parent-child relationships which were provided by the development contractor.

ARDB Partitioning - The ARDB is partitioned to parallel the requirements documents: Level 2 - Volume 1 by major section; Level 3 - by ECS segment/element and requirement identifier prefix. Exhibit 3-3 illustrates this partitioning.

Level 1	EOS Level 1 Project Plan
L2 Vol 1	ESDIS Level 2 Volume 1 (ECS) Requirements data bases
DADS	ECS DADS requirements data bases
EOC	ECS EOC (EOS Operations Center) requirements data bases
EOSD	ECS EOSD requirements data bases
ESN	ECS ESN requirements data bases
FOS	ECS FOS requirements data bases
ICC	ECS ICC (Instrument Control Center) rqmts data bases
IMS	ECS IMS requirements data bases
PGS	ECS PGS requirements data bases
SDPS	ECS SDPS requirements data bases
SMC	ECS SMC requirements data bases

EXHIBIT 3-3: IV&V ARDB Partitioning Schema

Exhibit 3-4 identifies the requirements documents subject to this analysis. Exhibit 3-5 identifies the sources of requirement linkages information.

LEVEL	TITLE	DATE
1	Execution Phase Project Plan For Earth Observing System, GSFC 170-01-01	9/93
2	Earth Data Information System Project ECS Volume 1 (Through CH19)	1/27/93
3	Functional and Performance Requirement Specifications for the EOS Data and Information Core System, Revision A CH-01	6/2/94

EXHIBIT 3-4: Requirements Documents Analyzed

3.3 Tools and Data Bases Utilized

Exhibit 3-2 lists the tools and data bases that were utilized in the evaluation of the ECS requirements along with the corresponding version/release number and their corresponding environment.

IV&V TOOLS	VERSION/RELEASE #	ENVIRONMENT
ARDB implemented using **Visual C++** **Excel** **Word**	**2.0** **5.0** **6.0**	**PC**
Novell Netware LAN WorkPlace	**2.5.4**	**PC**
RTM	**2.3**	**Sun**

EXHIBIT 3-2: Tools and Databases Used

Automated Requirements Data Base (ARDB) - The Automated Requirements Data Base (ARDB) is the repository for the requirements analysis and traceability data. This data is stored in a hierarchy of subdirectories containing spreadsheets. The spreadsheets contain analysis metrics and links to electronic Requirements Technical Analysis Forms on over 3,000 requirements. They also contain documentation and graphics. The ARDB Windows Interface is designed to manage the task of accessing this data by providing an easy to use menu structure in a windows environment. This menu structure eliminates the need for a detailed knowledge of the requirements structure, so that analysts can easily find the desired data. The Windows interface can also be used to control access to the data and manage the object linking necessary to create and examine the Technical Analysis Forms in their format as Word documents. The IV&V analysts utilized this tool to evaluate requirements in a consistent manner.

Novell Netware LAN Workplace - The Novell Netware LAN Workplace is being used for information transfer between team members. This group of tools supports the transferring of files from the Sun to the PCs, which enables the import of RTF files produced in RTM. These imported files may then be subjected to key word searches to support analysis.

Requirements Traceability Management (RTM) Tool - The analysis made extensive use of the RTM tool (by Marconi - Sun/UNIX resident) to evaluate traceability between levels 2 and 3, utilizing a snapshot of the ECS contractor's data base as of late August. This COTS-based tool is used for information and requirements traceability throughout the EOSDIS IV&V life cycle. Since the tool is configurable, it also supports traceability of requirements to the design and implementation lifecycle components as well as test cases. The IV&V analysts used RTM

performed for ECS Level 3 F&PR Specifications [1]: Level 3 to Level 2 and Level 3 peer-to-peer.

3.1.2 Quality Evaluation

The Level 3 ECS F&PR Specifications [1] were evaluated for quality. Quality was measured by evaluating each requirement against evaluation criteria described in Appendix A to determine if the requirement is accurate, unambiguous, complete, flexible, and consistent.

3.1.3 Testability Evaluation

The Level 3 ECS F&PR Specifications [1] were evaluated for testability in accordance with the criteria described in Appendix A.

3.2 Constraints Affecting the Analysis

Existing automated RTM data bases are not yet integrated or fully populated with baselined requirements, particularly for Level 1. This necessitates the manual evaluation of document-embedded trace notations (particularly) between levels 1 and 2, and does not permit verification of the consistency between document content and automated data base representations.

The analysis of the ECS contractor provided RTM data base is based on a snapshot current as of the end of August. Therefore, any changes made after that time were not part of the analysis. Future analyses, to be fully effective, must address the most current state of the data bases. This can only be assured by maintaining electronic synchronization between each element's RTM data base and the IV&V image of them. The problem can be mitigated for future IV&V requirements analyses by utilizing RTM's data base partitioning capability and appropriate Project agreements.

An additional constraint affecting the analysis relates to missing data within the RTM data bases provided by the ECS contractor. Review of Level 2 requirements is partly affected by the system having incomplete paragraph identification for all requirements. Currently, data base paragraph identification for Level 2 requirements only contains the item identification (i.e., "a.") but not the associated numerical paragraph prefix. Thus, users are prevented from obtaining requirement listings by section. This appears to be a result of the initial loading effort since the data structure does duplicate the layout within the original document. Entries should be corrected to include the full paragraph identification in order to facilitate reader understanding and future analyses.

3.0 METHODOLOGY AND APPROACH

This section describes the IV&V methodology and the technical approach utilized to perform this requirements analysis. Appendix A describes the overall IV&V requirements analysis methodology.

3.1 Analysis Tasks Performed

Exhibit 3-1 is adapted from the EOSDIS IV&V Independent System Verification and Validation Plan (ISVVP) [4] and illustrates the total potential scope of EOSDIS IV&V requirements analyses. The requirements analysis activities performed for this effort are indicated by the √ symbol. The methodology used in the analysis is described in Appendix A.

	Level 1	Level 2	Level 3	Level 4
Traceability	N/A			
ECS		Yes √	Yes √	Yes
EDOS		Yes	Yes	Yes
Ecom		No	No	No*
Quality	No			
ECS		Yes	Yes √	Yes**
EDOS		Yes	Yes	Yes**
Ecom		No	No	No
Testability	No			
ECS		Yes	Yes √	Yes
EDOS		Yes	Yes	Yes
Ecom		No	No	No

EXHIBIT 3-1: Requirements Analysis Scope

Yes = If authorized by task assignments and assuming adequate resources are available

* Traceability linkages for Ecom are accepted, without analysis, from the Ecom IV&V contractor

** If resources or tasking for full Level 4 requirements analysis are not available, Level 4 requirements will only be analyzed to determine if ambiguities found at Level 3 have been satisfactorily resolved.

3.1.1 Traceability Evaluation

Two traceability analyses were performed for ESDIS Level 2 Volume 1 EOSDIS Core System Requirements [2]: Level 2 to Level 1 and Level 2 to Level 3. Two traceability analyses were

2.4 Background Information

This analysis has been performed as a part of EOSDIS IV&V Task 5 (Requirements Analysis and Traceability), more specifically Subtask 5.1 (Preliminary Requirements Analysis). Due to the simultaneous IV&V contract start and Task initiation, in addition to the actual analysis of ECS requirements, this effort also required extensive, concurrent IV&V support development activity:

- Tailoring the standard IV&V requirements analysis processes to the needs of the EOSDIS,
- Designing and implementing the IV&V Automated Requirements Data Base (ARDB) and tools to efficiently support the tailored processes (assisted by EOSDIS IV&V Task 4), and
- Importing the ECS developer's Requirements Traceability Management (RTM) data base containing traceability information to higher level.
- Obtaining traceability data for Mission To Planet Earth (MTPE) requirements by requesting a report from a SEIMSS maintained RTM data base.

2.5 References

1. Functional and Performance Requirements Specification for the Earth Observing System Data and Information System (EOSDIS) Core System, 423-41-02, 6/2/94.

2. Earth Science Data Information System Project (ESDIS), Level 2 Requirements EOSDIS Core System (ECS) Volume 1, 423-10-01-1 Revision A (through Change 19).

3. Execution Phase Project Plan For Earth Observing System, GSFC 170-01-01, 9/93.

4. EOSDIS IV&V Independent System Verification and Validation Plan (ISVVP), Intermetrics, October 17, 1994.

2.0 INTRODUCTION

This introduction section of the EOSDIS IV&V "EOSDIS Core System (ECS) Preliminary Requirements Analysis Report" discusses the purpose, objectives, and scope of the requirements analysis, and includes relevant background information and reference material.

2.1 Purpose of the Report

The purpose of this technical analysis report (TAR) is to document the results of an independent ECS requirements analysis conducted by the EOSDIS IV&V team over the period 17 June 1994 to 28 October 1994. This TAR documents existing and potential problem areas, including their relative severity and possible adverse implications for the ECS development, overall EOSDIS validation/certification, and user satisfaction.

2.2 Objective of the Analysis

The objective of this requirements analysis is to assess the technical integrity (the traceability, quality, and testability attributes - which will be further discussed in section 3.1) of the ECS functional and performance requirements (F&PR) specifications contained in the 2 June 1994 baseline [1]. Specifically, the analysis identifies, characterizes, quantifies, and recommends (where feasible) solutions to problems with the baselined requirements, missing or incomplete requirements, parent-child and peer-to-peer linkages, and the configuration management of requirements and linkages. Problems not inherently visible at the individual requirement level are also examined. The analysis further assesses the possible impact of identified and potential problems on the ability to successfully design, implement, and certify the overall EOSDIS, from both a system engineering and a user satisfaction viewpoint.

2.3 Scope of the Analysis

ECS associated requirements are analyzed for traceability across levels 1, 2, and 3. Quality and testability are analyzed for level 3 requirements only. EOS Data and Operations System (EDOS), EOS Communications System (Ecom), and other Project requirements are outside of the scope of the current analysis. The technical integrity of the requirements allocation to ECS releases (e.g., Interim Release 1) are not the subject of this analysis. Requirements criticality (their relative importance) and development risk (the uncertainty of achieving the desired system) analyses are also not included in this analysis. Requirements allocation, criticality, and risk will be addressed in subsequent analyses targeted at specific system releases.

1. Traceability problems, especially associated with links from level 2 Volume 1 to level 3 ECS requirements, are a serious concern,
2. The incomplete, and somewhat arbitrary, configuration management of linkages and release-specific level 3 requirements can have serious implications during later lifecycle phases,
3. Lack of requirement-to-requirement terminology and data definition integrity (clear definition and consistency of usage) is a major contributing factor to quality problems, and
4. The ICC to EOC interface is being treated as an internal interface and not as an ECS external interface.

We believe the following key recommendations would be of high-value to the ESDIS Project and to a successful EOSDIS:

1. Requirements linkages be configuration controlled by the ESDIS Project to the same extent that the requirements themselves are controlled,
2. Release-specific level 3 (i.e., the ECS contractor's level 3.5) requirements be configuration controlled by the ESDIS Project separately from overall level 3 requirements,
3. The interface between ICC and the EOC be treated as an external interface through creation of an IRD and ICD,
4. This analysis be repeated each time requirements at any level (1, 2, or 3) are rebaselined, tasking and resources permitting, and
5. EOS Data and Operations System (EDOS) requirements be included in future analyses and that the results of the EOS Communications System (Ecom) IV&V contractor analyses be incorporated.

Implementation of recommendations 1, 2 and 3 would help maximize overall technical integrity. Implementation of recommendations 4 and 5 would provide the ESDIS Project with a complete, up-to-date, consistent picture of overall EOSDIS requirements technical integrity.

1.0 EXECUTIVE SUMMARY

This technical analysis report (TAR) documents the results of an independent ECS requirements analysis conducted by the EOSDIS IV&V team over the period 17 June 1994 to 28 October 1994. The objective is to assess the technical integrity (the traceability, specification quality, and testability attributes) of the ECS functional and performance requirements (F&PR) specifications contained in the 2 June 1994 baseline. The analysis identifies, characterizes, quantifies, and recommends (where feasible) solutions to problems with: 1) the baselined requirements, 2) missing or incomplete requirements, 3) parent-child and peer-to-peer linkages, and 4) configuration management of requirements and linkages. The ECS associated requirements are analyzed for traceability across levels 1, 2, and 3. Quality and testability attributes are analyzed for level 3 requirements only.

The analysis made extensive use of the Requirements Traceability Management (RTM) tool (by Marconi - Sun/UNIX resident) to evaluate traceability between levels 2 and 3, utilizing a snapshot of the ECS contractor's data base as of late August. Additional tooling is PC LAN resident and consists of a set of spreadsheet metrics data bases (MS Excel) linked to associated analysis rationale data bases (MS Word). The metrics/rationale data bases are partitioned to parallel the requirements documents: level 2 - Volume 1 by major section; level 3 - by ECS segment and requirement identifier prefix. Problem metrics are quantified into four levels of severity - major, moderate, minor, and none. Exhibit 1-1 illustrates this partitioning and summarizes the number of requirements exhibiting problems, by level of severity, including a count of those with no identified problems. Problems not inherently visible at the individual baselined requirement level (i.e., those related to a collection of requirements, associated with missing requirements, etc.) are evaluated and reported but are not currently quantified in the metrics data bases.

Level 2 Volume 1	Total No	Major Problems			Moderate Problems			Minor Problems			No Problems		
Requirements	of Rqts	Trace	Qual	Test	Trace	Qual	Test	Trace	Qual	Test	Trace	Qual	Test
Vol 1 S-3.1.1 Gen'l/etc	69	29	n/a	n/a	1	n/a	n/a	8	n/a	n/a	31	n/a	n/a
Vol 1 S-3.1.2 Func/etc.	183	58	n/a	n/a	20	n/a	n/a	12	n/a	n/a	93	n/a	n/a
Vol 1 S-3.2 Evolve/etc.	16	4	n/a	n/a	1	n/a	n/a		n/a	n/a	11	n/a	n/a
Level 2 Vol 1 Total	268	91	n/a	n/a	22	n/a	n/a	20	n/a	n/a	135	n/a	n/a
Level 3 ECS	**Total No**	**Major Problems**			**Moderate Problems**			**Minor Problems**			**No Problems**		
Requirements	**of Rqts**	**Trace**	**Qual**	**Test**	**Trace**	**Qual**	**Test**	**Trace**	**Qual**	**Test**	**Trace**	**Qual**	**Test**
ECS EOSD (Sys Lvl)	125				2			5	28		118	97	125
ECS SDPS DADS	196				2	4	1	3	26	7	191	166	188
ECS SDPS IMS	193				1	3		2	28	2	190	162	191
ECS SDPS PGS	104	2				2	2	11	23	6	91	79	96
ECS SDPS SDPS	29	1						1	7		27	22	29
ECS FOS EOC	176				1	8	6	25	4	1	150	164	169
ECS FOS FOS	6				1				1	1	5	5	5
ECS FOS ICC	211				11	5	3	1	4		199	202	208
ECS CSMS ESN	66				1				1		65	65	66
ECS CSMS SMC	145		7		3	3		18	1		124	134	145
Level 3 ECS Total	1251	3	7	0	22	25	12	66	123	17	1160	1096	1222
n/a: Not Analyzed (Out of scope of this analysis)													
Note: Row values may not sum to total number of requirements since a requirement can exhibit multiple problem levels													

EXHIBIT 1-1: Summary of Identified Requirements Problems

The analysis yielded several key findings:

TABLE OF FIGURES

TABLE OF CONTENTS

EOSDIS CORE SYSTEM (ECS)
PRELIMINARY REQUIREMENTS ANALYSIS REPORT

(Deliverable #0502)

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